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THE HEALTH WORK OF THE LEAGUE OF NATIONS.[1]

By VICTOR G. HEISER.

(*Read February 4, 1927.*)

One of the great achievements of modern civilization has been to prevent the transmission from country to country of communicable diseases. With increasing knowledge this has become more effective, until now, through the health work of the League of Nations, it has reached a high point of development. This branch of activity of the League of Nations is in reality a continuance and enlargement of the objectives of international sanitary conventions that have been in existence for many years.

Nations have sought to safeguard themselves largely through regulating maritime commerce. It is a very general belief that the health of Europe and America has been seriously menaced by the great unwashed hordes of the Orient. Apparently little thought has been given to the fact that at times the diseases of Europe have caused serious consequences for the people of the Far East. For instance, when Captain Cook and other intrepid explorers made their voyages to the South Seas, they took with them tuberculosis, smallpox, syphilis, gonorrhea, measles, and other diseases which were entirely unknown among the islanders of the South Pacific. The havoc wrought by the importation of these diseases stands among the great disasters of history. The unfortunate island people have suffered terribly through their contact with western civilization. They have been almost wiped out by the diseases which were introduced among them. An obligation therefore appears to rest upon our civilization to help control a situation that threatens a complete extermination of such a race as the Polynesians, for example.

In the days before transmission of disease was understood, it became empirically known that communicable diseases could be largely avoided by detaining infected persons in isolation for sufficiently long periods of time; forty days was regarded as a safe period, and from

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that the word "quarantine" derives its origin. In the beginning, sanitary conventions were usually made effective between two countries. Gradually it became apparent that a group of countries could act to better advantage. For instance, when the Suez Canal was completed, it was obvious that all traffic from the East would have to pass through this very narrow neck of water. A veritable funnel was created into which a large part of the earth's population might pour its disease. By taking precautions at the entrances to the Canal, Europe could largely be safeguarded. An international quarantine service was established at Suez. The United States was loosely affiliated with this organization. In order to handle the traffic, stations were opened at Port Said and Suez. For ships that required detention of passengers, a gigantic quarantine station was installed at El Tor, with a capacity for quartering several thousand persons at a time.

Another development to control the international movement of disease came when sanitary safeguards were thrown around huge religious pilgrimages. It is an established fact that movements of large numbers of people, particularly fanatical religious groups, have been an important factor in spreading disease throughout the world. Prior to the World War, in order to save Europe from diseases of the Near East, an international sanitary committee was established at Constantinople, which prescribed certain precautions, particularly in connection with ships. As knowledge in the prevention of disease increased, it became obvious that sanitary conventions would require more frequent revision. But it was difficult to have adequate international representation at sanitary conferences, because the delegates usually had to be chosen from among the active administrative health officers, and they could not spend the many weeks away from home that were required to revise a convention.

With the advent of the Health Section of the League of Nations, workable machinery was provided which made it possible, through the health representatives of the various nations stationed at Geneva, to exchange opinions and work out solutions which could be presented at an international sanitary convention. In view of the varying needs of the countries and the constantly increasing scientific knowledge, it was difficult, even with the improved machinery of the League

of Nations, to formulate a convention which could have the adherence of all the countries of the world. It is obvious that under the old method employed before the existence of the League, it would have been almost impossible to work out a convention that could have had general approval. As soon as the Health Section of the League of Nations was established, it concerned itself with this matter. And it was largely the data collected under auspices of that body which enabled the International Convention held in Paris last May to arrive at an agreement within a month.

But the Health Section of the League performs many other important functions. Soon after it came into existence in 1919, Europe was confronted with the serious menace of typhus fever spreading from Russia westward. In the disorganized Europe that existed after the armistice, no one country was in position to establish the sanitary safeguards which were necessary in order to control an epidemic of such huge proportions. As the League could act for all of the countries directly concerned, an organization under its auspices was quickly perfected, which established disinfestation stations along the Russian border; and Europe was saved from a serious invasion of typhus, no doubt largely because of the excellent work done. The United States unquestionably benefited very greatly. Had Europe become seriously infected, we should have been compelled to undertake precautions on a very large scale. It may not be out of place to mention in passing that all of the countries belonging to the League of Nations, including Japan, China, and even little Siam, and other countries not menaced, paid their share to control an epidemic, that Europe might be saved from invasion; and we—a great rich, powerful nation—enjoyed the benefits of this work and made no contribution.

Soon afterward, as a result of the war between Greece and Turkey, thousands of Greeks were expelled from Turkey. It was not long before a severe smallpox outbreak occurred among the refugees. It was obvious that if Greece should become thoroughly infected with smallpox, the infection would in all probability spread to Europe. Again the United States would have been seriously threatened. Here was another task that obviously no one country could undertake for itself. It was perfectly apparent that the surest way to safe-

guard Europe would be to vaccinate the population of Greece. Again no nation could make such a proposal to a sovereign country. The League of Nations stepped in and offered its services, which were accepted. And owing to the extensive vaccinating done in Greece under League auspices, the epidemic was quickly brought under control and Europe and America were again saved.

The enormous extent of the traffic on the Danube is well known. Many countries border on this great artery of trade. The multitude of conflicting quarantine regulations of the different countries proved most embarrassing to commerce. Through the intervention of the League of Nations a set of uniform rules and regulations was adopted by the interested countries, which protects them as well as may be against invasion of disease, and places the minimum restriction upon commerce and international passenger travel.

Upon the request of the countries of the Far East, the League of Nations made a study of the possibilities of disease control through better international action. This finally resulted in the establishment by the interested nations of headquarters at Singapore, of which the primary object is the collection and dissemination of data relating to the dangerous communicable diseases. Such free interchange of information has made it possible greatly to improve the quarantine administration and to give timely notice of impending dangers. The office is conducted as a branch of the League of Nations in Geneva. Telegraphic reports are received at Singapore from thirty-nine countries, which are freely reporting their dangerous communicable diseases. To a very large extent suspicion and retribution have been replaced by confidence and common-sense action.

One of the modern means of dealing with disease is through the use of vaccines and serums commonly known as "the biologicals." As each country has been working more or less independently, a set of diverse standards has resulted. This has caused great confusion. For instance, a diphtheria antitoxin unit valued at 1 in Germany would be valued at 67 in the United States and at 2,500 in France; and still other standards are used by other nations. It is obvious that a doctor studying the reports of a foreign physician must be a mathematician; and if, as is frequently the case, he is in ignorance of what particular country's vaccine or serum is used, he is greatly

handicapped in his study of disease. A uniform standard seemed desirable—but how was it to be obtained? Here again the Health Section of the League of Nations showed its value by appointing an international committee, which made thorough research into the matter; and it is hoped that in a short time a uniform standard will be adopted, thus eliminating the confusion which has existed in the past.

If disease is to be dealt with intelligently, accurate bookkeeping of its incidence is necessary; it is obvious that vital statistics are essential in making comparative studies. Until recently, almost every country had a different system for recording such data, so that comparisons were more or less impracticable. The League of Nations called a meeting of representatives of the various interested countries, who sent their statisticians. After a study of the matter, a system was devised which will make uniform international adoption possible. The importance of using the same classification can scarcely be estimated. For instance, it was found that certain forms of cancer are apparently twice as prevalent in Great Britain as in Holland. The mere fact that attention has been brought to this matter will stimulate research, for there must be some good reason for this difference. Many other important data are in the process of being revealed through this uniform system of reporting.

Another outcome of the statistical meeting has been the establishment in Geneva of an office of epidemiological intelligence, which collects data with regard to communicable diseases from the entire world and issues weekly bulletins. Member nations that are in the direct path of an oncoming disease are promptly notified by telegraph and thus are able to take timely precautions. In the past there has been all too much effort on the part of many countries to suppress news with regard to outbreaks of quarantinable disease, thus unnecessarily menacing other countries. The free interchange of knowledge which is now on a fair way toward accomplishment will no doubt do much to improve the control of these diseases.

Another activity has been the establishment of an interchange of sanitary personnel among the different countries. By this is meant that the League of Nations invites one or more health officers from various nations, organizes them into a group, and sends them to other

countries to study the health measures employed. This has had a most stimulating effect. Countries that have good health departments have been glad to show their work; those that have not been so fortunate have been stimulated to do something better. The free interchange of opinions which has occurred among the various health officers frequently results in improved measures. The travels of these international groups have also brought about much newspaper publicity, which in itself has been for the advancement of public health. Many of the countries feel that their prestige has been enhanced by having foreign officers visit their work and report upon their activities.

The League has also made a study of the sanitary organization of many countries in the world and has published the results. This has made it possible to compare the health administration of the different countries, and those that were found backward have been making renewed efforts to improve their health measures. The maps which have been published, showing the extent of disease incidence, have had a most salutary effect.

The United States has always taken a prominent part in an effort to bring about suppression of the use of habit-forming drugs, notably opium and cocaine. Those especially interested, however, soon found that the League of Nations was the logical means to employ, if they wanted detailed information, or an international conference, or international action. And already two opium conferences have taken place under League auspices.

A large part of the Central African continent cannot be developed successfully on account of the prevalence of sleeping sickness, and this is a vital problem to numerous nations. Need for international action is again obvious. A combination of effort promises the greatest hope of finding satisfactory measures for control, and the League of Nations has been asked to nominate an international committee to deal with this matter.

Encouraged by the success which has followed international action in the control of yellow fever, the League of Nations has directed its attention to the possibility of performing a similar international service in the control of cholera. For some years now experts have been giving this disease serious consideration, and a number of researches

have already been made. In view of the very large number of countries in which cholera prevails, international action will be required if a uniform plan is to be agreed upon. Special studies are being made on certain phases of cholera. The results of these, combined with findings made in other places, may make it possible to devise a hopeful plan for controlling the disease. There is much reason to believe that from time to time cholera recedes to a few endemic centers, and when enough knowledge is available with regard to the disease, it is hoped to extinguish those centers and clear the world of a menace which has caused the loss of so many lives.

One of the great advantages of having an international office at Geneva is that it provides a storehouse where the world's knowledge with regard to the control of disease can be assembled and where investigators can find data and facilities for study. No one country, without the expenditure of huge sums of money—and even then the outcome would be very doubtful—can have such a library of information as is gradually coming into existence at Geneva. Comparing data such as have been accumulated there has already brought forth some very significant observations. For example, in the United States we are rather prone to pride ourselves on the high state of our achievements in the field of disease prevention, yet comparison of records shows that the United States ranks with the most backward countries of the world in maternal death rate. It is three times as dangerous to be a mother in the United States, for instance, as in Denmark. The mere fact that it is possible to make such statistical comparisons will no doubt result in renewed efforts in the United States to bring down the death rate from maternal mortality, the causes for which are largely preventable. Again, a study of the records has shown that hookworm disease is largely exported by one country, from which perhaps a million or more laborers emigrate yearly. Instead of trying to mop up the disease after it has been spilled all over the world, it would be a simple matter to control it at its source. In other words, if emigrants leaving an infested country were treated with an effective hookworm remedy, the export of the disease would be largely stopped; but what is everybody's business is nobody's business, and consequently the dissemination goes on.

The League is obviously in position to draw attention to a matter of this kind and no doubt coöperation could be had.

Probably malaria ranks among the most important preventable diseases in its ultimate effects and in the economic loss it entails. In India, for instance, over a million people die annually of this malady. And even here in the United States the number of deaths for which it is responsible, and the time lost by illness, with the resulting economic losses, are stupendous. Every year our Southern States suffer frightfully, and it so happens that malaria reaches its peak in September, which is precisely the month during which the cotton crop has to be picked, and the period during which the lumber activity reaches its greatest height. We have, therefore, through this disease, the minimum labor at the time when the maximum work is to be done, with the resultant unnecessarily increased cost of production. Malaria is receiving attention in many countries of the world, but through lack of coöperation and knowledge of what is being done in these countries, many unnecessary experiments are being made. In order to assemble the world's knowledge in this matter, the League has appointed a malaria commission, which is making studies of the disease in Europe, the Near East, the Orient, and the United States. It is reasonable to expect that when the data are assembled, more effective measures will result and much unnecessary experimenting can be avoided.

Inquiry developed the fact that all remedies proposed for malaria, with the exception of quinine, had little or no effect in the cure of the disease. It was further shown that one country had gradually acquired a monopoly in the production of quinine, that the cost had accordingly risen over 200 per cent, and that in the absence of competition the chances for a reduction in price were not promising. Literally thousands of lives could be saved, if the cost of the drug could be reduced. The League focused attention upon this matter. Steps are being taken by Italy to grow its own quinine in Africa and Java. The British renewed their efforts to produce quinine in India. Research laboratories began work to discover, if possible, a synthetic drug to accomplish what quinine does. Within the past few months one of Germany's laboratories has announced the discovery of a drug that gives promise of being better in many respects than quinine itself.

It appears to be more effective than quinine in benign tertian malaria, and to kill the gametes in the blood. The latter is most important and may have great bearing in controlling the spread of the disease. When patients treated with quinine are not completely cured, they often serve as reservoirs of malaria from which Anopheles mosquitoes receive their infection and spread the disease. If the new German preparation, plasmochin, kills the gametes in the human blood, a great source of potential infection will have been eliminated.

The foregoing are only some of the activities in which the Health Section of the League of Nations has been engaged. There are many more that time does not permit me to describe in detail. Studies are being made on infant mortality, tuberculosis, cancer, social medicine, means to improve health administration in many countries, the minimum requirements for the education of health officers, and many other matters that concern the welfare of mankind. But important as are all of these efforts, there are by-products of the Health Section's work, the aggregate value of which bids fair to promote the peace and happiness of the entire world. The interchange of health officers among some forty countries has set up an international commerce in ideas that no customs barrier can interrupt. The mutual friendship and understandings that have resulted from these visits have already been important factors in interpreting the better qualities of one people to another. The exchange of scientific knowledge may eventually lead to the same method of analysis being applied to settle the ordinary differences among nations, and when that happy day comes, reason will replace hate and prejudice, and the well-being of the people throughout the earth will be greatly promoted.

BEHAVIOR OF ORGANIC BASES TOWARD SOLUBLE TUNGSTATES.[1]

By EDGAR F. SMITH.

(*Read December 4, 1926.*)

In 1861 Scheibler,[2] in his classic paper on tungstates, alluded briefly to the precipitation of tungstic acid from solutions of the 5 : 12-sodium salt (sodium paratungstate) by means of a slightly acidulated solution of quinine sulphate. The results showed that the procedure was quantitative in character but Scheibler withheld his recommendation of the method because the resulting ignited tungsten trioxide was never *yellow* in color, but had a greenish hue.

This was the first attempt to introduce an organic base as a precipitant of tungstic acid. Some years later Allen Rogers, working in this laboratory, found that benzidine precipitated tungstic acid completely from solutions of normal sodium tungstate $Na_2WO_4 \cdot 2H_2O$). And, thereafter, v. Knorre published an interesting communication on the use of benzidine chloride, in the determination of the tungstic acid content of sodium paratungstate.[3] It would seem that v. Knorre also used *tolidine* with success and expressed the hope that by these precipitants the separation of tungstic and phosphoric acids might be realized. However, a silence, not explained, fell upon these recommendations.

In the meanwhile, Tschilikin[4] recommended the precipitation of the tungstic acid in sodium tungstate ($Na_2O \cdot WO_3 \cdot 2H_2O$) with alpha-naphthylamine, asserting it to be a reagent as valuable and efficacious as the bases employed by v. Knorre. Further, he analyzed

[1] Contribution from the John Harrison Laboratory of Chemistry, University of Pennsylvania, Philadelphia, Pa.

[2] *Jr. prakt. Ch.*, **83** (1861), p. 288.

[3] The 5 : 12-sodium salt,—$5Na_2O \cdot 12WO_3 + 28H_2O$, as described in the *Z. für analyt. Chemie*, **47**, 37; *Ber.*, **38** (1905), 783.

[4] *Ber.*, **42**, 1302 (1909).

the alpha-naphthylamine tungstate obtained by him, and from the results deduced the formula

$$2(C_{10}H_9N_2)\cdot 5WO_3 + 3H_2O,$$

which doubled would be:

$$4(C_{10}H_9N_2)\cdot 10WO_3 + 6H_2O,$$

analogous to Wolcott Gibb's 4:10-sodium salt, and for reasons known only to himself Tschilikin also analyzed v. Knorre's benzidine tungstate, getting beautiful results confirmatory of the ratio two of base to five of tungstic acid, or the ratio 4:10, confirmatory also of the ratio of the salt

$$4K_2O\cdot 10WO_3 + Aq.,$$

as deduced by Wolcott Gibbs. These were most gratifying observations in view of the doubt cast upon the ratio 4:10 as existing between sodium oxide (Na_2O) and tungsten trioxide (WO_3), although proof of the existence of the same ratio had been given by others.[5]

The thought suggested itself that it might be well to apply various organic bases to solutions of different soluble tungstates. In the work described in the preceding lines it was mainly with common insoluble tungstic acid, as found in normal sodium tungstate and para-sodium tungstate with which the analyst dealt, although in the para-salt it is now known that the common insoluble acid is associated with soluble or meta-tungstic acid.[6] Hence, solutions of normal (1:1), para- (5:12) and meta- (1:4) sodium tungstates, as well as ammonium meta-tungstate, were made up with the purpose of exposing all of them to the same precipitants. It was accordingly observed that benzidine hydrochloride precipitated the preceding salt solutions completely in the form of voluminous masses, readily washed by decantation, and when filtered, dried and ignited, gave tungsten trioxide perfectly yellow in color. The carbon burned away completely and with ease, leaving no trace of green in the residue.

[5] See *Jr. Am. Ch. Soc.*, 44 (1922), 2028.
[6] *Chemical News*, CXXIX. (1924), p. 198 et seq.

Two determinations with sodium para-tungstate ($5Na_2O \cdot 12WO_3 + 28H_2O$) resulted as follows:

(*a*) 1.0348 gram salt gave 77.35 per cent WO_3,
(*b*) 0.8699 gram salt gave 77.47 per cent WO_3,

while the calculated percentage of tungsten trioxide in the salt is 77.37 per cent WO_3. The precipitant employed was *benzidine acetate*. It was added to the cold tungstate solution, equaling 250 cc. in volume. The flocculent benzidine tungstate subsided promptly after the addition of a slight excess of the precipitant, and was collected upon a filter and then washed with dilute acetic acid. The dry precipitate and filter were ignited together. The ignition was easy; the residue was lemon yellow in color.

Parenthetically it may be stated that molybdic acid was also quantitatively precipitated by benzidine acetate.

A solution of pure ammonium meta-tungstate was prepared, every 5 cc. of which contained 0.4110 gram of tungsten trioxide. On precipitating two similar portions (5 cc. each, diluted to 250 cc.) with benzidine acetate, filtering out and washing the benzidine meta-tungstate with acetic acid, igniting to WO_3 and weighing, there were obtained:

(1) 0.4118 gram WO_3,
(2) 0.4105 gram WO_3.

In these precipitations the benzidine acetate was introduced from a burette, drop by drop, under vigorous stirring. The benzidine meta-tungstate subsided quickly. The reaction was so sharp that its end could readily be noticed. Thus, for each of the 5 cc. portions of meta-tungstate solution, 6.2 cc. of the benzidine acetate were required. This interesting deportment may yet be developed into a volumetric procedure. In an additional case another portion of ammonium meta-tungstate solution, 5 cc. in volume, was diluted strongly with water and heated. The volume of benzidine acetate required for the complete precipitation was 6.6 cc. The precipitate was permitted to stand over night; removed by filtration, washed and ignited. The residue weighed 0.4096 gram WO_3, slightly lower than the theoretical.

These examples show conclusively that meta-tungstic acid is fully

precipitated from solutions of its soluble salts by benzidine. Of course, this was supposed to occur, as the total tungstic acid in the sodium para-salt had been obtained on using this reagent.

It was further noticed that *aniline hydrochloride* did not precipitate solutions of normal sodium tungstate and ammonium meta-tungstate, but in a 5 : 12 solution it produced a white, curdy mass which seemed to be quantitative. However, the following singular deportment must be mentioned, viz.: if the 5 : 12 solution had been boiled and the *aniline hydrochloride* then added, there was no precipitation. The fact that aniline hydrochloride had precipitated the 5 : 12-salt solution in the cold, and *not* after it had been boiled, surely indicates an hydrolysis of the salt 5 : 12 into 1 : 1 and 1 : 4, neither of which when alone had been precipitated by the aniline hydrochloride.[7]

A second attempt was made with a cold 5 : 12 solution, but the precipitation was *not* complete, as the filtrate was blued by contact with Zn and HCl.

It developed that *o-Toluidine Hydrochloride* precipitated normal sodium tungstate, ammonium meta-tungstate and the 5 : 12-salt incompletely; at least, all the filtrates were turned blue on exposure to the action of metallic zinc and hydrochloric acid.

On adding *pyridine* hydrochloride to a solution of normal sodium tungstate (1 : 1) immediate precipitation did not occur; but after twenty hours a compound had separated, in the filtrate of which a deep blue color appeared on the addition of metallic zinc and hydrochloric acid. Incomplete precipitation was also noticed in the solution of the 5 : 12-salt, while in those of the meta-salt (1 : 4) precipitation was immediate and thought to be complete, so that two portions of an ammonium meta-solution, each containing in 5 cc. 0.2019 gram tungsten trioxide gave

a. 0.1955 gram WO_3 and 0.1840 gram WO_3.

The filtrates from these precipitates remained colorless, when acted upon with zinc and hydrochloric acid.

Three additional portions (5 cc. each) of the ammonium meta-salt solution were treated as before, every care being taken in the handling of the pyridine precipitates, which gave,

[7] *Chemical News*, CXXIX. (1924), p. 198.

(*a*) 0.1927 gram WO_3,
(*b*) 0.1964 gram WO_3,
(*c*) 0.1948 gram WO_3.

What caused these variations from the theoretical requirements? As before, the filtrate showed no color reaction. It had also been learned that an excess of pyridine hydrochloride exercised no solvent or deleterious effect on the pyridine meta-tungstate, and that 20 parts of water dissolved 1 part of pyridine meta-tungstate, although this solubility was very materially reduced by the presence of an excess of pyridine hydrochloride.

Was the color test (with metallic zinc and hydrochloric acid) reliable or very delicate? To learn more on this point, 0.2019 gram of tungstic acid in the form of ammonium meta-tungstate was dissolved in 5 cc. of water. One cubic centimeter of this solution, equivalent to 0.0404 gram of tungstic acid, was diluted to 50 cc. and acted upon with the reducing agents. After an hour's standing, a slight purple coloration made its appearance. Again, 5 cc. of the solution in which there were 0.2019 gram of WO_3, had removed from it 1 cc.—.0404 gram WO_3, and this was diluted to 50 cc. and tested with like result, indicating that where not more than .04 gram WO_3 was present reliance could not be placed on this particular color reaction.

It seemed to be of interest to subject a portion of the pyridine meta-tungstate to a preliminary analysis; accordingly, 1.1758 gram of the salt was dried for a period of four and again of seven hours at 100° C., when it lost 0.0228 gram. The residue and crucible weighed 14.2825 gram. After ignition it left 0.9600 gram of WO_3 or 83.26 per cent. Assuming pyridine meta-tungstate to have the formula $(C_5H_5N)_2O \cdot 4WO_3$—the theoretical percentage of tungstic acid would be 84.21 per cent.

A second portion of pyridine meta-tungstate, treated as the first portion, gave however 84.21 per cent WO_3 in complete accord with the theoretical requirement, so that it may be proper to express the formula of this interesting body as

$$(C_5H_5N)_2O \cdot 4WO_3 + 2H_2O.$$

It seemed advisable to try out the action of quinine sulphate or chloride on sodium salts of insoluble and soluble tungstic acid.

Using a solution of sodium meta-tungstate (5 cc. of which contained 0.2026 gram WO_3)—there resulted:

(*a*) 0.2012 gram WO_3,
(*b*) 0.2029 gram WO_3,
(*c*) 0.2028 gram WO_3,
(*d*) 0.2022 gram WO_3,
(*e*) 0.2037 gram WO_3.

In these trials an excess of quinine sulphate was employed. The quinine meta-tungstates were almost snow white in color, whereas the precipitates formed in solutions of normal sodium tungstate and in sodium para-tungstate were tinged with a flesh-color. The meta-tungstate in every case left on ignition a beautiful lemon yellow colored trioxide—WO_3.

Two portions (5 cc. each) of the normal salt (1 : 1) solution were precipitated with an excess of quinine sulphate from solutions of 250 cc. volume. The filtration was made after standing two hours. The precipitates were washed with cold water containing quinine sulphate. The quantity of tungstic acid present in each instance was 0.1700 gram WO_3. There was found:

(*a*) 0.1704 gram WO_3,
(*b*) 0.1697 gram WO_3.

From two other portions, after letting the quinine tungstate stand an hour before filtration, there were obtained 0.1686 gram WO_3 and 0.1696 gram WO_3. The filtrates were not turned blue by action of zinc and hydrochloric acid.

In a third trial with the 1 : 1-salt solution, allowing the precipitate to stand four and a half hours before filtration, the quantity of tungstic acid obtained was 0.1700 gram, and upon still another, where the precipitate had stood twenty-four hours before filtration, there was found 0.1694 gram WO_3, so that the period during which the precipitate may stand before filtration occurs, may vary through a pretty wide range.

In none of these experiments were *blue* colorations by zinc and acid permitted finally to determine whether the precipitation had been complete; on the contrary, an aliquot portion of the filtrate was care-

fully evaporated to dryness and the residue examined for tungstic acid.

Turning to the 5 : 12-salt solution, it was found on precipitating it with an excess of quinine sulphate and allowing the same to stand for six days and six nights before filtration, that the resulting yellow colored WO_3 weighed 0.1903 gram instead of 0.1907 gram required. Also, that in portions which had stood over night the resulting tungsten trioxide weighed:

(*a*) 0.1907 gram,
(*b*) 0.1907 gram.

All these trials demonstrate that tungstic acid in its insoluble and soluble form may be estimated by the use of a quinine salt in excess. Care must be exercised carefully to wash out sodium sulphate. It tends to cling to the quinine salt.

It is established that quinine and cinchonine are similarly constructed; they contain one hydroxyl group, and quinine containing an additional methoxyl group is therefore methoxycinchonine, and cinchonidine is probably a stereo-isomeride of cinchonine. Because of this interesting relationship of the three basic bodies, cinchonine and cinchonidine were also studied analytically with normal, para- and meta-salts of the tungstic acid, and omitting the recital of individual experiments, it may be added that they all precipitated the acid quantitatively. It was to be expected, yet care must in all instances be observed to remove excessive sodium salts from the precipitates, otherwise the results will be high; this was particularly the case with cinchonine and cinchonidine, hence these reagents are not likely to be widely used in analysis.

Other observations noted in the course of this study were that quinine and cinchonidine precipitate solutions of sodium molybdate, while *nitron* precipitates the latter, as well as solutions of ammonium meta-tungstate. Chromatropic acid did not affect solutions of normal or meta-sodium tungstate. It is also true that *salicin* is without effect upon solutions of normal sodium tungstate, sodium para-tungstate or sodium meta-tungstate.

The several salts studied in this work were exposed to various solvents with the hope that results might follow which would have

value in determining constitution. Thus, it was observed that *nitrobenzene* had no solvent effect upon anhydrous normal sodium tungstate, sodium para-tungstate, ammonium meta-tungstate or pyridine meta-tungstate, nor was the latter soluble in *acetone*.

In *aniline*, normal sodium tungstate, sodium para-tungstate, sodium meta-tungstate and ammonium meta-tungstate were insoluble. They behaved similarly with *pyridine*. Anhydrous normal sodium tungstate was insoluble in *carbon disulphide*.

Summary.

1. That the organic bases to which reference has been made are good precipitants for the quantitative estimation of the tungstic acid content of soluble salts.

2. That both forms of tungstic acid—the ordinary insoluble acid, and soluble or meta acid—in their soluble salts, are removed by the specified bases.

3. That the blue color reaction occasioned by metallic zinc and hydrochloric acid in solutions of tungstates is not reliable when small amounts of the tungstic acid are present; that all filtrates from precipitates should be evaporated to dryness and the residues tested for tungsten by some more dependable reagent.

4. Strong evidences are at hand that benzidine as chloride or acetate may yield a rapid and accurate means of determining tungstic acid volumetrically.

5. Certain organic solvents were applied to the various soluble tungstates and found to be valueless on the score of solubility.

AN INTERESTING BEHAVIOR OF SOLUBLE META-TUNGSTATES.[1]

By EDGAR F. SMITH.

(*Read December 4, 1926.*)

Very strong proofs [2] have been presented that such compounds as sodium para-tungstate or the 5 : 12-sodium tungstate—$5Na_2O \cdot 12WO_3 + 28H_2O$; the 4 : 10-sodium tungstate—$4Na_2O \cdot 10WO_3 + 23H_2O$, and the 3 : 7-sodium tungstate—$3Na_2O \cdot 7WO_3 + 16H_2O$, —are combinations of normal sodium tungstate (1 : 1-$Na_2O \cdot WO_3$) with sodium meta-tungstate or 1 : 4-sodium tungstate ($Na_2O \cdot 4WO_3 + 10H_2O$). The 5 : 12-salt, the 4 : 10-salt, and the 3 : 7-salt were not only resolved into normal sodium tungstate (1 : 1) and sodium meta-tungstate (1 : 4), but were synthesized by the union of definite amounts of the normal sodium and the sodium meta-salts. Every chemist is familiar with the strong basic character of aqueous solutions of normal sodium tungstate and the diametrically opposite, acid nature of sodium meta-tungstate solutions. In the antiquated formulations of chemistry such bodies as 5 : 12-, 4 : 10- and 3 : 7-sodium tungstates arose from the union of a very basic body like $Na_2O \cdot WO_3$ with the intensely acid substance—$Na_2O \cdot 4WO_3$. What would occur on bringing in contact aqueous solutions of sodium chromate ($Na_2O \cdot CrO_3$) and sodium molybdate ($Na_2O \cdot MoO_3$) with sodium meta-tungstate? To answer this interrogatory there were mixed

First, definite amounts of normal sodium chromate in solution, and sodium meta-tungstate. The mixture was gently boiled for five minutes. Soon the liquid became turbid and assumed an intense red color, due to the production of sodium bichromate. The liquid was filtered. The insoluble portion was white tungstic acid. The deep red colored filtrate stood over night, and by morning there had sepa-

[1] Contribution from the John Harrison Laboratory of Chemistry, University of Pennsylvania, Philadelphia, Pa.

[2] *Chemical News*, **129** (1924), p. 198.

rated a copious mass of crystals. One recrystallization gave them in colorless forms, strongly suggestive of crystals of the 4: 10-sodium tungstate. These were recrystallized and analyzed, when they yielded water, tungstic acid and alkali in accord with the requirements of the formula

$$4Na_2O \cdot 10WO_3 + 23H_2O.$$
$$8.33\% \quad 77.79\% \quad 13.86\%$$

On adding a cold solution of ammonium meta-tungstate to a solution of normal sodium chromate (Na_2CrO_4) the yellow color of the latter slowly assumed a red color. The change, however, was very rapid on the application of a gentle heat. Just as in the previous example, ordinary white tungstic acid separated, and from its filtrate, crystallized colorless forms which, on analysis, gave 13.35 per cent and 13.65 per cent of water, and 77.52 per cent of tungstic acid, again indicating the production of the 4: 10-sodium salt.

Would normal sodium molybdate ($Na_2MoO_4 + 2H_2O$) combine with sodium meta-tungstate to yield complexes, as did sodium tungstate ($Na_2WO_4 + 2H_2O$) and sodium meta-tungstate? To determine this point, definite quantities of sodium molybdate and sodium meta-tungstate were brought together and their aqueous solution warmed, when gelatinous tungstic acid separated, and in its filtrate beautiful twinned crystals appeared. These were purified. A portion on analysis gave 13.24 per cent H_2O, 77.52 per cent WO_3 and 9.24 per cent Na_2O (by difference), which would confirm the production again of the 4: 10-sodium salt.

A second portion of the same salt was exposed at 250° C. to the action of dry hydrogen chloride to expel any molybdic acid, if it existed in the crystalline body. It was not found. These behaviors are noteworthy. There was almost a conviction that sodium molybdate, at least, would yield a combination analogous to

$x\ Na_2O \cdot WO_3\ y\ Na_2O \cdot 4WO_3$; thus, $x\ Na_2O \cdot MoO_3 \cdot y\ Na_2O \cdot 4WO_3$,

but the experiments showed the opposite to be the case.

MARTINICHTHYS—A NEW GENUS OF CRETACEOUS FISH FROM KANSAS, WITH DESCRIPTIONS OF SIX NEW SPECIES.

By C. E. McCLUNG.

This is one of several nearly related genera belonging to no well determined family (Albulidæ, Elopidæ, Osteoglossidæ according to Woodward; Plethodidæ—Hay; Elopidæ, Plethodidæ, Albulidæ—Loomis). It has been confounded with the genus *Protosphyræna* by Cope and Hay because of the presence of a rostrum, but is, in fact, far removed from it. Up to the present time, only fragments of the skull have been known, and while the rostral portion indicated relations to the genus *Protosphyræna,* studies made from the occipital and parasphenoid region of certain other skulls led Loomis to found new genera which Hay regards as synonymous with *Anogmius.* It is not possible to determine with certainty whether the material before me belongs to Loomis' genus *Syntegmodus,* and I am, therefore, proposing the name *Martinichthys*[1] to designate the genus. I am led to do this partly because of the indefinite character of the type specimen of Loomis and partly because he figures parasphenoids of *Martinichthys* which he describes as belonging to a different genus from *Syntegmodus.* The descriptions of parts of two crania, with numerous vertebræ and rostra of seven different kinds, indicating as many species, will be given.

Definition of the Genus Martinichthys.—Skull high, rostrum short, more or less blunt, sometimes apparently worn on cephalic end, varying from slender to heavy in different species. Parasphenoid flattened on ventral surface and bearing pits or denticles, joined dorsally to alisphenoid and orbitosphenoid. Interorbital septum present. Mandible long in comparison with skull. Hyomandibular forming articulation with skull by a depression in the pterotic. Glossohyal long, flat and apposed to parasphenoid to form buccal mill.

[1] In honor of Mr. H. T. Martin of the Palaeontological Museum, University of Kansas, who has long been interested in the rostra of this form.

Dentition weak, confined to small denticles distributed over various bones of the mouth. Vertebræ completely ossified, small, delicately sculptured, pitted dorsally and ventrally. Fins and tail unknown.

MARTINICHTHYS BREVIS—new species, Specimen No. 497. Genotype.

Cranium.—The cranium of the type specimen measures 140 mm. from the end of the rostrum to the occipital condyle and 47 mm. from the ventral edge of the condyle to the supraoccipital crest. It is crushed laterally, and the two hyomandibulars lie against the median series of cranial elements. The greatest width in the parietal region, restored, is 50 mm. The rostrum, on the ventral surface, is 43 mm. long and its greatest width is 30 mm. Its median cephalic surface is cleft for about 2 mm; the ventral surface is flat and covered with denticles, or pits for their reception; the dorsal surface is arched and covered with pits or grooves. The caudal edge is irregular in outline and, laterally, covers a deep groove for the reception of the prefrontals. On the mid ventral surface of the cranium, extending from the basisphenoid to the vomer, is the parasphenoid, 80 mm. long and 24 mm. in greatest width near its caudal end. The ventral surface is approximately flat and pitted, like the rostrum, for holding denticles. The articular surface of the occipital condyle measures dorsoventrally 12 mm. Interorbital septum well developed, as in *Syntegmodus* and *Anogmius*. There is a large orbitosphenoid and a smaller alisphenoid, both articulating ventrally with the parasphenoid. So far as can be determined from the specimens at hand, there is a continuous median partition between the two halves of the skull which, dorsally, diverges on each side, forming a partly enclosed brain case. I do not find evidences of a presphenoid such as is described by Hay for *Anogonius altus*. The appearances in *Martinichthys* are more nearly like what is represented by Loomis for *Syntegmodus*.

Mandible.—The mandibles are represented only by the imperfect right mandible showing the articular, connected with the quadrate, and the symphysial end. Between these extremities only a fragment, representing the more ventral part of the jaw, remains. The articular shows a strong dorsally projecting process that passes externally to the quadrate. In the region of the symphysis the dorsal edge is preserved and this shows a broadened margin covered by small denticles. The extreme length is 93 mm.

Palatine.—A flat, triangular bone, 30 x 65 mm., lies beside the parasphenoid and assists in forming the roof of the mouth. It is pitted on the ventral surface like the parasphenoid. The extreme width of the parasphenoid and of the two palatines in position would be 80 mm.

Hyoids.—In this specimen there are preserved the ceratohyals, basihyals, hypohyals and glossohyal, all in position but crushed laterally. The extreme length of the series in this specimen is 80 mm., of which the ceratohyals measure 43 mm. The glossohyal is large, deeply pitted dorsally and strongly supported by the hypohyal ventrally. When apposed to the parasphenoid, of equal length, it formed an efficient grinding apparatus. There are no evidences of urohyal or of branchiostegals.

Denticles.—A number of the bones in the mouth are pitted and have been described by Loomis as having a covering of a peculiar substance, which he calls "osteodentine." Hay fails to discover any peculiar material of this nature, but describes canals extending into the bone and also small sand-like teeth on the ridges. It would appear from my observations that there are a number of the mouth bones, which are very similar in construction of their external surfaces. In the specimen of *Martinichthys brevis* the parasphenoid, palatines, rostrum and glossohyal are thus pitted, and where they do not come into contact with other similar bones are covered with small, hollow, pointed denticles. Where these are broken off, it can be seen that their central cavity extends down into the bone upon which they rested. Upon the triturating surfaces these denticles give way to a ridged and pitted surface which, in life, was probably covered by a corneous and thickened skin. Such denticles appear in a number of genera.

Martinichthys ziphioides (Cope).

1877, *Erisichthe ziphioides,* E. D. Cope, Bull. U. S. Geol. & Geog. Survey of Terr., III., p. 823.

1878, *Protosphyræna ziphioides,* E. T. Newton, Quart. Jour. Geol. Soc., XXXIV., p. 795.

1890, *Protosphyræna ziphiodes,* J. Felix, Zeit., Deutsch Geol. Gesellsch., XLII., p. 297.

1895, *Protosphyræna ziphioides,* A. S. Woodward, Cat. Fos. Fishes, Brit. Museum, III., p. 413.

1900, *Protosphyræna ziphioides,* F. B. Loomis, Palaeont., XLVI., p. 222.

1903, *Protosphyræna ziphioides,* O. P. Hay, Bibliog. and Cat. Fos. Vert. N. A., p. 379.

1903, *Protosphyræna ziphioides,* O. P. Hay, Bull. Am. Mus. Nat. Hist., XIX., Art. 1, p. 22.

Type specimen No. 2131 is in the American Museum of Natural History.

In 1877 (p. 822) Cope described from the chalk of Kansas a specimen of fish which he placed in his genus *Erisichthe* and to which he gave the specific name *ziphioides.* This specimen, now in the American Museum of Natural History, No. 2131, was described by Hay ('03 p. 22), who confirms Cope's identification. Felix ('90, p. 297), quotes Cope's description and dismisses the species with little more consideration. So far as I can discover, there has been no further notice of this interesting fish. Two good specimens in the museum of the University of Kansas enable me to correct several errors in previous descriptions, and to remove definitely the species from the genus *Protosphyræna* into the new genus *Martinichthys.*

The most complete specimen so far obtained (No. 498), was collected by Mr. H. T. Martin during the summer of 1909 in Trego County, Kansas. It consists of the axial complex of cranial bones and a series of 25 vertebræ. As may be seen from an inspection of accompanying figures, this is a very different fish from *Protosphyræna.* The conspicuous dentition of the latter animal is entirely lacking, and in its place appears the pitted bones so characteristic of *Anogmius.* This and the presence of well ossified vertebræ is sufficient to remove the form from *Protosphyræna,* to which it was attached purely on account of the presence of a rostrum.

From the descriptions of Cope and Hay, it will be observed that the rostrum is materially different from that of *Protosphyræna,* the difference indeed being so extensive as to lead both of these authors to describe the dorsal surface as the ventral. Two pits on the dorsal surface, similar to the alveoli of the vomerine fangs of *Protosphyræna,* led to the belief that these were identical structures. Be-

cause of the absence of functional teeth here, and also on account of the short, blunt rostrum, Cope surmised that the specimen studied was the remains of an old individual with an abraded and worn snout. Hay did not regard this explanation of Cope's as plausible, but agreed with him in conceiving the rostral depressions as alveoli of the vomerine teeth.

The material before me forms the picture of an animal very different from Protosphyræna. The extreme length of the skull from tip of rostrum to occipital condyle is 200 mm., of which the complete rostrum occupies a little more than 50 mm., so that in the matter of size there is considerable difference. The entire structure of the skull so far revealed in the new genus is lighter and more delicate than that of *Protosphyræna*. This difference is shown very strikingly in a comparison of the parasphenoids, for in *Martinichthys,* instead of being a strong massive element, it is slender and delicate in construction. Most striking, however, is the entirely opposite types of dentition in the two genera. *Protosphyræna* presents a type of the highest development in dental armature, with its strong, sharp, and firmly socketed teeth on the maxillaries, premaxillaries and vomers, while in the new genus there is an apparent absence of teeth except weak denticles disposed over the roof and floor of the mouth.

Since the rostrum is the most prominent and striking element of the skull, as well as its most common representative among fossils, it would seem desirable to describe it in some detail. In general, the description of Hay, l.c., is accurate, except for the confusion of the dorsal and ventral aspects, but additional features appear in the new specimens. Two of these specimens (Nos. 506, 507) are very similar in size and extent to that of Cope and Hay. They are figured on Pl. I., Figs. 8 and 9. Very striking, indeed, is the triangular roughened surface on the ventral aspect, which is sharply outlined by a shallow groove terminating on each side at the cephalic end by a deeper depression, the two being separated by a short tongue of bone extending caudally for a short distance in the median line. The area thus enclosed, for a distance of 50 mm. caudally from the cephalic apex is much roughened, suggesting the presence, in life, of a hardened, closely applied cartilaginous covering, probably having denticles. This terminates somewhat abruptly, leaving exposed the smooth

surface of the vomers, interpreted as the frontal by Hay. On each side of this is a deep pit, which is homologous with similar ones in *Protosphyræna,* for the reception of the premaxillaries. The tip of the truncate rostrum is smooth and in this specimen marked by two sharply defined rounded pits on its inclined cephalic extremity. Upon the side of the rostrum and forming the outer boundary of the groove enclosing the triangular roughened area, previously mentioned, is a narrow triangular bone, its apex directed cephalad, and its caudal portion just beside the pit for the reception of the premaxillaries. This is the bone which, in *Protosphyræna,* Felix calls the " ethmoidale laterale." Upon the dorsal surface appears another triangular bone, again the apex being cephalad, which represents either the frontal or prefrontal.

The entire surface of the rostrum is roughened, not as in *Protosphyræna* by a regular pattern of raised lines, but irregularly—an exception to this being the inclined tip of the rostrum, which is smooth.

Rostra of Five New Species.

Following are brief descriptions of six rostra, clearly belonging to five different species. Owing to their incomplete condition, no full account can be given. So far only two rostra have been found in connection with their skull, those of *M. ziphioides* and of *M. brevis,* but the close resemblance between the three specimens of *M. ziphioides* before me leads me to believe that we may expect some degree of specific constancy in the structure of the rostrum. This seems the more probable also in view of the considerable diversity manifestly appearing in the ones ascribed to other species and because of the resemblance between the two included in the species *acutus.* The figures from 1 to 10 of plate I., give clear views of these different rostra and supplement the brief descriptions.

Martinichthys acutus—new species, No. 502.

Rostrum 17 x 27 mm. Short, pointed, with cephalic surface slightly inclined. In cross section, circular, smooth, without pits, except four on cephalic surface. (Fig. 6.)

Another specimen (No. 503), 17 x 29 mm. Similar, except it is somewhat flattened dorso-ventrally, and has two pits in cephalic end. (Fig. 5.)

MARTINICHTHYS GRACILIS—new species, No. 504.

An incomplete rostrum, now 21 x 55 mm. When complete it was probably 70 mm. long. (The longest rostrum as yet discovered.) Tapers gently toward the cephalic end. In cross section a flattened oval; surface smooth and only slightly pitted. Ventral surface flat. (Fig. 3.)

MARTINICHTHYS ALTERNATUS—new species, No. 500.

Rostrum 42 mm. long, 15 mm. wide. Dorsal surface straight, ventral surface inclined, forming an angle of about 20 degrees with dorsal. In this specimen the cephalic one third of the ventral surface forms an angle of about 45 degrees with the dorsal. (Fig. 2.)

MARTINICHTHYS LATUS—new species, No. 499.

Rostrum 40 x 73 mm., truncate, cephalic surface inclined, extending forward further on left than on right side, roughly pitted. Ventral surface crushed, but rough and finely pitted. In cross section, oval. This is the largest and heaviest rostrum so far discovered. (Fig. 4.)

MARTINICHTHYS INTERMEDIUS—new species, No. 501.

Rostrum 25 x 52 mm. Free portion short, cephalic-ventral surface rounded and forming an angle of about 45 degrees with the dorsal. (Fig. 1.)

DESCRIPTIONS OF FIGURES.

Specimens discussed in this paper are in the Palaeontological Museum of the University of Kansas. Most of them were secured in a direct effort to determine the character of the fish from which the rostra of *M. ziphioides* had come. In this way the very complete skull of specimen No. 497 was found by the author.

(This paper was originally prepared for the proposed S. W. Williston memorial volume.)

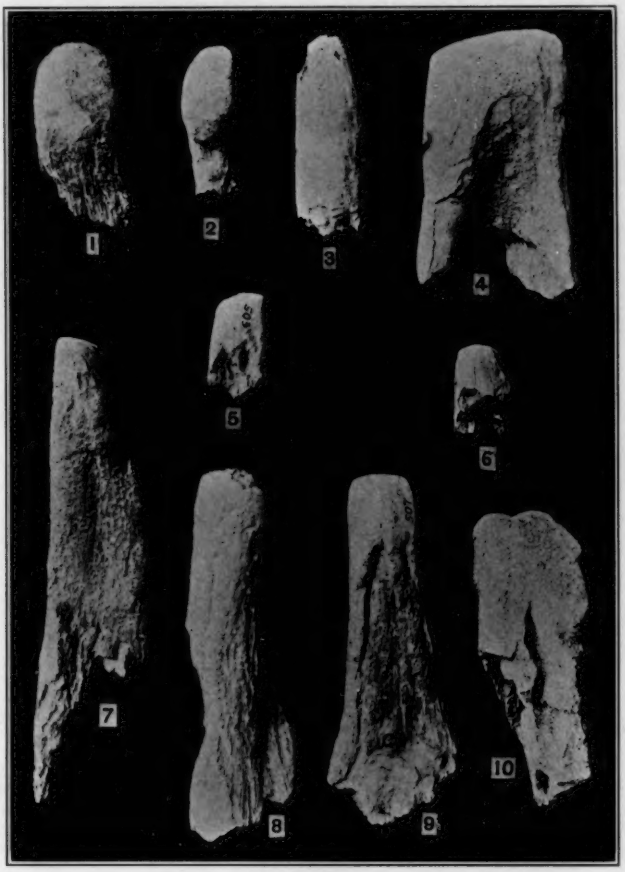


FIG. 1. Rostrum of *M. intermedius.*
FIG. 2. Rostrum of *M. alternatus.*
FIG. 3. Rostrum of *M. gracilis.*
FIG. 4. Rostrum of *M. latus.*
FIG. 5. Rostrum of *M. acutus.*
FIG. 6. Rostrum of *M. acutus.*
FIG. 7. Rostrum of *M. ziphioides.*
FIG. 8. Rostrum of *M. ziphioides.*
FIG. 9. Rostrum of *M. ziphioides.*
FIG. 10. Rostrum of *M. brevis.*

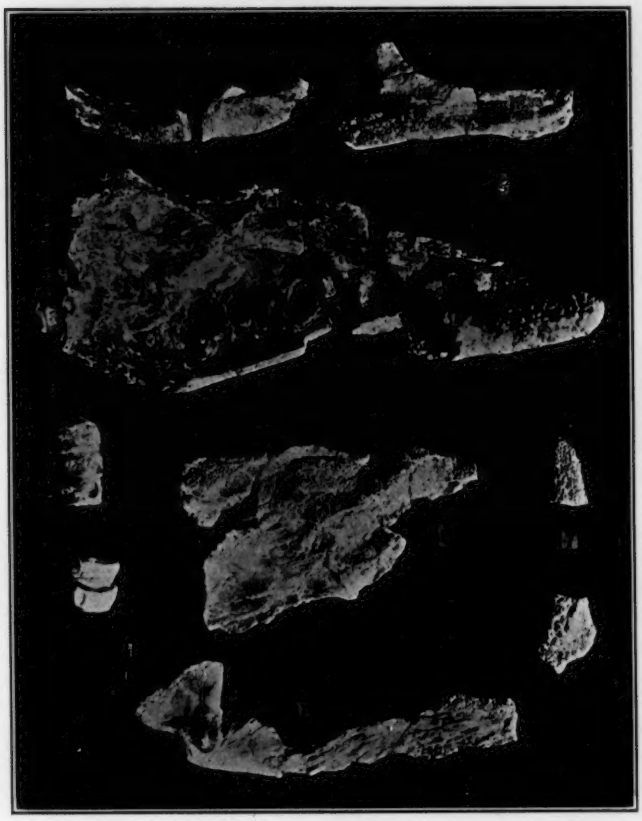


PLATE II.

FIGS. 11–17. Bones of the skull of *M. brevis* with five vertebræ.
FIG. 13. Lateral view of axial series of cranial bones.
FIG. 15. Lateral view of mandible and quadrate.

THE FLORA OF THE SERRA DA BOCAINA.[1]

By BERTHA LUTZ.

Introduction.

During his numerous expeditions to various parts of Brazil, Dr. Adolphe Lutz did not limit himself exclusively to the collecting of zoologic material or to work along his own special lines of research. Following the bend of the naturalist, interested in every aspect of nature and wishing to have a real knowledge of the regions visited, he made additional botanical studies and collected the more characteristic plants. As a result, he has acquired in the course of some years quite a large sized herbarium, which contains a great many interesting phanerogams.

He has now intrusted me with the revision and the cataloguing of his collections and I cannot help thinking that it is of a certain interest to publish the results. At the present state of knowledge concerning the Brazilian flora it seems obvious that much may be gained by studies concerning the regional aspects of the vegetation of this country and the distribution of species both in altitude and extension.

Dr. Lutz's herbarium includes plants from many parts of Brazil, chiefly from the hydrographic basin of the river S. Francisco, the northeastern states, the Paraná river, the Federal District and surrounding country, and the states of Rio de Janeiro, São Paulo, Sta Catharina and Minas Geraes.

I might have begun with any of these but finally decided to start the cataloguing with the plants from the mountain range of the Bocaina, which is a part of the maritime chain known as the " Serra do Mar."

This region has been visited by Dr. Lutz many times, at different

[1] A lesser-known region of Brazil's maritime range.

[2] Owing to her early departure for Brazil, Miss Lutz did not see the proofs of this article. Dr. Harshberger kindly gave them a careful examination.

seasons and much of the material for his original systematic work in entomology and other branches of zoölogy was collected here.

The flora of the Bocaina mountains is interesting in many ways. To begin with, it is hardly known to botanists, except for two excursions made by Glazious in 1864 and 1876, and a few modern ones, if I am not mistaken. For another thing, this range is lower than the Itatiaya, the part of the Mantiqueira chain which is only about 50 km. from it and running almost parallel to it. It is also nearer to the sea and offers consequently somewhat different conditions, especially as to rainfall. Finally, the flora of the mountains is always interesting and especially so in Brazil, where it offers a rich and varied field, principally owing to the *campos* formations with herbaceous species of many families and curious adaptations to more or less xerophytic environments.

There is evidently much similarity between the flora of the Bocaina and that of other coastal ranges and it has many points of contact with the nearby Itatiaya. As is to be expected under the more favorable conditions above mentioned, many of the mountain species are found at lower ranges. As a curiosity we shall give a few of the species found in both ranges, together with some indications as to their comparative altitudes.

Species.	Altitude.		
	Itatiaya.	Bocaina.	Difference.
Syphocampylus longipedunculatus	1,850	1,150	700
Lobelia camporum	1,900–2,400	1,350–1,580	550– 820
Coccocypselum condalia	1,900	1,300	600
Utricularia globulariaefolia	2,300–2,500	1,150	1,150–1,350
Nicotiana langsdorffii	2,200	1,150–1,250	1,050– 900
Leucothoë intermedia	2,300–2,500	1,300	1,000–1,200
Hypericum brasiliense	1,900–2,200	1,150	750–1,050
Rubus erythroclados	1,850	1,250	600
Prunus sphaerocarpa	1,850	1,150	700
Escallonia montevidensis	1,900–2,200	1,150	750–1,050
Berberis laurina	2,000–2,300	1,580–1,600	420– 700
Sophronitis grandiflora	2,300	1,600	700
Burmannia bicolor	2,000	1,500	500
Araucaria brasiliana	2,100–2,300	1,150	950–1,150

The altitudes given for the Itatiaya are those indicated by Dusen in his article on the flora of the Itatiaya, published in *Archives do*

Museu Nacional, Vol. XIII (1905), pp. 1 ff. Those of the Bocaina are at the points where Dr. Lutz and I found them, the altitudes being given in accordance with the measurements taken by Dr. Mario Roxo, a distinguished engineer, who has gone over the Bocaina and taken measurements many times.

This is of interest principally with regard to the plants considered as belonging to alpine or andine families, such as the Ericaceae and Ranunculaceae on one side; the Escalloniaceae and Berberidaceae on the other.

Some of the species considered by Dusen as belonging to the lower flora of the Itatiaya are also found at still lower altitudes on the Bocaina, as for instance:

Species.	Altitudes.		
	Itatiaya.	Bocaina.	Difference.
Mutisia coccinea	1,400	1,150	150
Salvia guaranitica	1,800	1,350	450
Hydrocotyle quinqueloba	1,800	1,150–1,300	650–700

It is only fair, however, to point out that these indications may be by no means absolute. There are also some exceptions to the general rule. *Anemone sellowiana,* for instance, was found by Ule in the Itatiaya already at an altitude of 1500 meters, although not in flower. Dr. Lutz, on the other hand, found the same species only at from 1,580 to 1,600 meters.

Phytogeographic Aspect.

According to the information given us by Dr. Mario Roxo, the larger part of the zone we travelled over was originally tropical rain forest, not only where it is still wooded, but also in much of the actual open country. The *"native campos"* only appear at the higher points to which we penetrated, such as the Ponte Alta and the Morros da Boa Vista, over 1,600 m.

In the old times, before the Central Railway of Brazil came into being, a trail used to lead up to the Bocaina mountains from the sea, passing through luxuriant forest, in which ferns were very plentiful.

We did not have the opportunity to use this trail, but approached

from inland over the hamlet of Formoso. Collecting was consequently not begun until a certain height was reached and the railway journey continued on horseback. Our plants are from above 1,000 meters altitude, with the exception of a small specimen of Fridericia speciosa, which was gathered at about 500 m.

Owing to difficulties of transportation, the radius of the excursions mentioned in this paper was not very great, going from the settlement at Formoso to the region called Bonito and from the Fazenda of that name to Ponte Alta and the bar of the river Mambucaba.

Consequently, we shall merely describe the localities as we found them and not as they were before the changes brought about by man in the original phytogeographic aspect.

Interesting Families and Species Found.

Among the more interesting plants occurring in the Bocaina we may cite: *Equisetum Martii,* a tall species found by Dr. Lutz in the month of January; *Bomarea spectabilis,* blooming in September and October, 1913, and *Amaryllis* (*Hippeastrum*) *psittacina,* which generally grows on humus-covered rock, but is epiphytic in trees at the Bocaina.

Only in the one excursion which I accompanied in January, 1925, we saw well over twenty species of Orchids, among them quite a number of *Oncidium,* several of them growing on stones like a species of *Epidendrum,* probably *elongatum* and some terrestrial representatives of this family. *Sophronitis grandiflora* was found in two places above 1,500 m. flowering in February. We looked for it in January, 1925, but did not find it. It was probably too early in the season, for it has been seen since.

On a damp spot in the woods by the banks of the river Bonito a balanophoraceous plant, *Helosis guyanensis,* was found in January, both in 1915 and in 1925, though much less developed the second time.

Berberis laurina and *Anemone sellowiana,* both very interesting mountain species, are found but are rather rare and only appear at higher elevations.

On the Boa Vista hills there grows an extremely ornamental apocynaceous climber, a species of *Mandevilea* (*Amblyanthera*) with

large beautiful rose-colored blossoms with yellow inner side of the corolla tube. They are fully 8 cm. long. It does not entirely fit any of the descriptions found in the scant literature at our disposal.[2] We were unable to consult the description of 45 species as indicated by K. Schumann, in Engler u. Prantl's " Die nat. Pflanzenfamilien." Comparison with Gardner's herbarium of the South Kensington Museum, made in 1914 by Dr. Lutz, did not lead to its determination, though it seemed nearest to *M. seleowii.* We shall give a short description of it at the end of this paper.

There are several Gentianaceae, considered as one of the more interesting families found in the mountain campos of Brazil. A scarlet *Lysianthus* grows on one or more of the hills, but is unfortunately retreating from the invasion of its territory by a bracken fern. Another one, which is blue, is rarer; there is also a small lemon-colored one. A *Dejanira* also grows in the Bocaina. It is similar to *embescens,* but has white blossoms. We shall describe it also, since it differs from those known to us. Besides these we have *Voysia uniflora* and *Zygostigma australe.*

The Gesneraceae are represented by quite a number of species, some of them common, like *Gesnera alagophylla,* known in Brazil as *potato of the fields,* on account of its round tubers found on the surface of stones and fallen tree trunks, and to a lesser degree *Hypocyrta hirsuta. Gesnera cooperi* is very handsome on the rocks that litter the course of mountain streams, and its brilliant blossoms are enhanced by the rays of sunlight filtering through the woods. *Gesnera maculata, Gesnera magnifica,* and *Codonophora prasinata,* the last two extremely handsome, are also among the plants gathered on this range.

The Melastomaceae and the Compositae include, as always in Brazil, the most plentiful species. In the Bocaina the Melastomaceous and Compositous plants are very variable in habit, from minute xerophytic species to great arborescent or climbing ones.

Distribution.

Forest.—Though much of this region must originally have been wooded, nowadays the forest is interrupted by large tracts of open

[2] " Flora Brasiliensis," etc.

country and finally becomes reduced to the depressions in the slopes of the mountains from which the rolling native campos begin to rise. There are some very tall species in the woods. Of those in flower we must mention huge specimens of *Clethra Brasiliensis*, the flowers of which are very difficult to obtain. *Vochysia* is represented in the woods by two different species. At the falls of the Cavalhada, near the Fazenda of the Bonito, there grows a very nice specimen of *Prunus sphaerocarpa*. There are some *Leguminosae*, of course, arborescent *Melastomaceae* and a very frequent species of *Croton*, with long pointed drip-leaves, that turn yellow and scarlet. In the garden of the Fazenda are two imported olive trees that have fruited once. There are some specimens with buds in the herbarium.

Among the climbers in the woods there are a few Melastomaceae and the composites *Bidens rubifolius*, *Wedelia subvelutina* and *Mutisia coccinea*, several Bignoniaceae, among them two *Opithecoctenium*, a red passion flower, and *Fuchsia integrifolia*, which grows everywhere in the mountains of S. Paulo and Minas.

Brunfelsia ramosissima and *hydrangaeformis*, both bushes, occur in these woods, mostly with very poor foliage, a condition probably due to insects.

In the upper woods we came across two Loranthaceae, a *Phoradendron* and a *Strutanthus*, I believe.

The lesser vegetation includes some *Polygalas*, a few earth orchids and a *Burmannia*, found in one place only but very abundant there. The creeping ground vegetation includes these species of *Hydrocotyle: Centella asiatica Bacopa* (*Herpestes*) *chamaedryoides*, *Viola cerasifolia*, *Drymaria cordata*, etc.

One copse, found near Bonito de Cima, with much drier soil than the woods, seems entirely made up of *Belangera tomentosa Styrax leprosum* (?) and a *Solanum* that was not determined.

River Banks.—The banks of the river, especially the Bonito, which in this region flows in a long and relatively narrow valley, are occupied in some spots by three Escalloniae. In January they are decked with white blossoms, like an orchard in spring, but I believe they flower for a longer period. Several small mountain streams come down from the higher mountains. In one of these, a tributary of the Bonito, going under the picturesque name of the Secret River

(Segredo), we once came upon the floating blossoms of a Papilionacea, considered a "*Timbó*" (a name given to the plants considered poisonous for fishes). It was a *Camptosema pinnatum.*

Valley of the Bonito River. In this valley are found small "pinheitaes," *i.e.,* groves of *Araucaria brasiliana,* which become very extensive in the south of Brazil, where the Serra do Mar gradually subsides, but where the latitude produces lower temperatures than would be afforded at similar altitudes in more northern zones. The higher elevations like the Bocaina, however, seem to compensate this, for the pines thrive just as well as further south. There are no other trees found together with the Araucariae. On these grow a small Orchid, probably a *Pleurothallis* and a *bromelia, Aechmea sp.* in which the Dynastor Napoleon moth has been observed to breed, and from which we raised caterpillars some years ago. Underfoot grows *Hydrocotyle* in the damp places and in the more common dry ground thrive two *Verbenas, V. hirta* and *V. rigida,* and *Cuphea mesostemon.* In the open places of the valley are found *Phytolacca thyrsiflora,* and *Nicotiana langsdorffii,* supposed to appear where clearings have been made. *Verbascum blattarioides* also rears its tapers.

It is interesting to note that some of the pasture grounds of the Bonito Fazenda are overgrown with *Achillea millefolium,* which must have been imported unwittingly. On the edges of the paths and roadsides in this valley and elsewhere a *Gomphrena* and a *Baccharis* are constant. There is some damp ground in this valley, and when this occurs, two *Haynaldia* and several species of *Habenaria,* among them the aptly named *sartor,* appear. Here *Cestrum corymbosum,* a more ornamental representative of this modest genus, appears.

Swamps.—In the swamps found in the Bonito valley and sometimes in the forest clearings the vegetation is made up of *Utricularia globulariaefolia,* three kinds of *Xyris,* some Eriocaulonaceae (others grow in the dry campos) and a *Begonia* with bright pink blossoms and red undersides of leaves. The latter makes brilliant splashes of colors in the bogs.

Campos.—The flora of the *Campos* is very interesting indeed. Some of the species found are very plentiful and overrun whole hills. Others, on the contrary, seem rare and localized. Among the com-

mon ones I should like to mention *Diclieuxia polygaloides,* with bluish stems and *Vernonia tomentella,* a hairy and resinous composite. *Tibouchina* minor is plentiful and pretty with its large well-formed flowers and gradually diminishing leaves, the lowest of which are tiny and pressed to the ground.

Lobelia camporum is found nearly everywhere. There is also a plentiful little *Polygala* with very narrow leaves.

In the higher campos *Microlicia isophylla* is the characteristic plant. It may begin to flower as early as January and is still found in bloom in June. Its vulgar name is " vassourinha," or little broom.

As is only to be expected, there are several Ericaceae in the Bocaina, chief among them *Gaultheria ferruginea* and *elliptica, Gaylussacia villosa,* and a *Leucothoe,* which does not entirely agree with the diagnosis in the " Flora Brasiliensis," but comes nearest to *intermedia.* I distinctly have the impression that this genus is in need of revision; some of the descriptions overlap considerably and possibly there are fewer species, and these more variable than one supposed at first.

Some of the campos plants are localized in a very few places. This is true of the handsome Apocynaceae mentioned, of some of the *Lysianthus* and *Alophia. Eryngium* of two species are found in isolated spots.

The plants growing above 1,200 meters show more or less xerophytic characters. Some display a covering of hairs, as *Gaultheria* and *Gaylussacia,* others have leathery leaves pressed against the stems. Some contain strong resins and many are small with showy flowers and reduced external vegetative organs. The vegetative apparatus is reduced to the minimum in *Chevreulia acuminata,* which might easily be taken for a moss. There are also *xerophytic* species of other Compositae and some very small Oxalidaceae in Glaziou's collections represented in the Herbarium of the Brazilian National Museum. Some have more than one xerophytic character. *Vernonia tomentella* may serve as an instance of this.

I should like to have an opportunity to make a more extensive comparison of the vegetation of the Bocaina with other ranges, both of the Maritime range and with other serras, but for the moment must confine myself to this initial contribution, which I consider far from complete.

Follows a list of the species found, with the dates at which they were in bloom. The collections were made in the years 1912, 1913, 1914, 1915 and 1925. In this last excursion, made at a very rainy season, I took part. The months of the year were January, February, April, June, September, October, and December, all of them represented in the collection, but most of all the first months of the year. The specimens referred to in the catalogue are to be found in the Instituto Oswaldo Cruz, with duplicates at the National Museum. Some of the Orchids were given to the botanical garden of this institution for cultivation, with very indifferent results.

The plants were determined almost entirely by Dr. Lutz and myself, under great difficulties, owing to the very scant literature. Glaziou's collections helped somewhat. *Oxypetalum sublanatum* was determined by A. Hoehne from S. Paulo, and Professor Sampaio of the National Museum gave some indications as to the Orchids. We thank them both, as also Dr. W. Roberto Lutz, his daughter and son-in-law, at whose fazenda we stayed during these excursions. I also wish to tender my gratitude to Dr. Mario Roxo for the indications as to altitude and other interesting data of this region, which he gave me very readily indeed.

EQUISETACEAE.

Equisetum Martii Milde. Leg. A. Lutz, 16 a 31, Dec. 1915.

TAXACEAE.

Podocarpus Lambertii Klotzsch. Leg. B. Lutz (Ponte Alta), Jan. 1925.

ARAUCARIACEAE.

Araucaria brasiliana (A. Rich) Lamb.

XYRIDACEAE.

Xyris sp., Jan. 1925.
Xyris sp., Jan. 1925.
Xyris sp., Jan. 1925.

ERIOCAULONACEAE.

Actinocephalus pohlianus, Jan. 1925.
Paepalanthus itatiayae, Jan. 1925.
Syngonanthus caulescens Rub., Jan. 1925.

JUNCACEAE.

Juncus sp., Jan. 1925.

LILIACEAE.

Smilax montana? Grieseb., Jan. 1925.

COMMELINACEAE.

3 undetermined species.

AMARYLLIDACEAE.

Alstroemeria inodora Herb., Feb. 1915, Jan. 1925.
Amaryllis (*Hippeastrum*) *psittacina.*
Bomarea spectabilis Schenck., Dec. 1915.

DIOSCOREACEAE.

Dioscorea sinuata Vell., Jan. 1913, Jan. 1925.
Dioscorea piperifolia Willd., Jan. 1913, Jan. 1925.

IRIDACEAE.

Calydora (*Roterbe*) *campestris* Klatt, Jan. 1913.
Alophia geniculata? Klatt., Jan. 1913, Jan. 1925.
Sisyrhinchium incurvatum, Jan. 1913, 1925.
Sisyrhinchium incurvatum, March 1917.

BURMANNIACEAE.

Burmannia bicolor Mart., Feb. 1915.
Apteria lilacina (*cultivada*) Miers, Jan. 1915.

ORCHIDACEAE.

Epidendrum elongatum Griesb., April 1913.
Sophronites grandiflora Lindl., April 1913, Feb. 1915.
Masdevallia infracta Lindl.?, Dec. 1915.
Govenia gardneri Hook., Jan. 1913, Jan. 1925.
Pogonia Rodriguesii Cogn., Feb. 1915.
Epidendrum fragranas Sw., April 1913.
Maxillaria sp., Jan. 1913.
Habenaria sartor Lindl., Jan. 1915, Jan. 1925.
Habenaria Reichenbachiana B. Rodr., Feb. 1925.
Habenaria sp., Jan. 1925.

Oncidium (5 undetermined species), Jan. 1925.
Zygopetalum sp., Feb. 1915.
Zygopetalum mackayi Hook., Jan. 1913.
Cyrtopodium sp., Feb. 1915.
Pleurothallis sp., Jan. 1925.

PIPERACEAE.

Peperomia marmorata? Sept.-Oct. 1913, Jan. 1925.
Others undetermined.

LORANTHACEAE.

Strutanthus sp., Dec. 1915.
Phoradendron sp., Jan. 1913, Feb. 1915.

BALANOPHORACEAE.

Helosis guyanensis Rich., Jan. 1915, Jan. 1925.

POLYGONACEAE.

Polygonum acre H. B. K., Feb. 1915.
Polygonum sp., Jan. 1925.
Triplaris sp., Feb. 1915.

PHYTOLACCACEAE.

Phytolacca thyrsiflora Fenzl., Jan. 1925.

CARYOPHYLLACEAE.

Drymara cordata W., Jan. 1925.

RANUNCULACEAE.

Anemone sellowii Pritz., Sept. 1913.

BERBERIDACEAE.

Berberis laurina Billb., Sept.-Oct. 1913.

LAURACEAE.

Ocotea (*Oreodaphne*) sp., Jan. 1915.
Ocotea (*Oreodaphne*) sp., Sept. 1913.

SAXIFRAGACEAE (ESCALLONIAE).

Escallonia mentividensis Cham. et Schl., Feb. 1915.
Escallonia vaccinoides St. Hil., May 1915, Jan. 1925.

Escallonia organensis Gardn., Jan. 1913, June 1915.

CUNIONACEAE.

Belangera tomentosa Camb., Jan. 1915.
Belangera cunionata Cambess., (Jan.?) 1913.

ROSACEAE.

Prunus sphaerocarpa Sw., Jan. 1915, Jan. 1925.
Rubus erythrocaldos Mart., Jan. 1925.

LEGUMINOSAE.

Camptosema (Dalstedtia) pinnata Malme., Jan. 1913, Jan. 1925.
Mucuna altissima D. C., March 1914.
Crotalaria striata D. C., Jan. 1925.
Collaea speciosa L., Oct. 1913.
Desmodium sp.
Cassia sp.
Mimosa sp.

OXALIDACEAE.

Oxalis sp., Jan. 1913, e 1925.
(Umbellasma ext. sup.)

SIMARUBACEAE.

Picramnia warmingiana Engl., Jan. 1925.

VOCCHYSIACEAE.

Vocchysia tucanorum Mart., Jan. 1913, March 1915, Jan. 1925.
Vocchysia oppugnata, Jan. 1925, June 1915.

POLYGALACEAE.

Polygala laurifolia B., Jan. 1915, Jan. 1925.
Polygala stricta? subulosa?, Jan. 1913, June 1915, Jan. 1925.

EUPHORBIACEAE.

Croton sp., Jan. 1913.
Croton sp.
Croton sp., Jan. 1925.
Manihot sp., Dec. 1915.
Acalypha sp., Jan. 1913, e 1925, Dec. 1915.

SAPINDACEAE.

Serjania sp., Jan. 1925.

MALVACEAE.

Pavonia speciosa H. B. K., Jan. 1913, Glaziou 1864.
(Subpolymorpha.)
Hibiscus sp., March 1915.

DILLENIACEAE.

Davillea rugosoa, Dec. 1915.

HYPERICACEAE.

Hypericum brasiliense Choisy. (Lambein Glaziou.)

ILICINACEAE.

Ilex affinis var. *angustifolia* Garden., Feb. 1915, Jan. 1925.

VIOLACEAE.

Viola cerasifolia St. Hil., Dec. 1915, Jan. 1913, Jan. 1915, Jan. 1925.

FLACOURTIACEAE.

Casearia cambessedessii Eichl., Jan. 1915.

PASSIFLORACEAE.

Passiflora rubra L., Feb.-Dec. 1915, Jan. 1925.

BEGONIACEAE.

Numerosas especies que deixamos de determinar.

LYTHRARIACEAE.

Cuphea mesostemon Koehne., Jan. 1925.

MELASTOMACEAE.

Tibouchina herbacea Cogn., Jan. 1925.
Tibouchina minor Cogn., Jan. 1915, e 1925.
Tibouchina minutiflora Cogn., L. 1913, Jan. 1925.
Tibouchina arborea Cong.
Tibouchina clinopodiflora Cong. (or *gracilis*), Glaziou 1876, Feb. 1913.
Trembleya parviflora Cogn., June 1915.
Leandra nutans Cogn., Dec. 1915.

Leandra sp.
Lavoisiera australe Cogn., Jan. 1913.
Microlicia isophylla D. C., Jan. 1913, June 1915, Jan. 1925.
Miconia theesans?, Jan. 1913.
5 Tibouchinas e 6 other not determined species.

MALPHIGHIACEAE.

Tetrapteris ou Heterapteris, March 1924.

ONAGRACEAE.

Fuchsia integrifolia Camb., Jan. 1913, Jan. 1925.

UMBELLIFERAE.

Hydrocotyle barbarossa Cham. Dec. 1915.
Hydrocotyle hirsuta, Jan. 1925.
Hydrocotyle quinqueloba, Ruiz et Pav., Feb. 1915, Jan. 1925.
Centella asiatica Urb., Jan. 1925.
Eryngium paniculatum D. C., Jan. 1913.
Eryngium glazioviamnum Urb., Jan. 1915.

CLETHRACEAE.

Clethra brasiliensis Cham., Jan. 1925.

ERICACEAE.

Leucothoë intermedia Meissn., Jan. 1913, Jan. 1925.
Gaultheria ferruginea Cham. et Sehl., March 1915, Jan. 1925.
Gaultheria elliptica Cham., June 1913, Sept.-Oct. 1915, Dec. 1915, Dec. 1917.
Gaylussacia villosa, Oct. 1913, Dec. 1915.

STYRACACEAE.

Styrax leprosum? Hook. et Arn., Dec. 1915, Jan. 1925.

OLEACEAE.

Olea europea L., end of Sept. 1913.

GENTIANACEAE.

Dejanira sp., March 1914.
Lysianthus elegans, Jan. 1913, e 1925.
Lysianthus alpestris Mart., Jan. 1925, March 1914.

Lysianthus sp., Jan. 1913.
Voyria uniflora Lam., June 1915.
Zygostigma australe Gries., Jan. 1913, Feb. 1915.

APOCYNACEAE.

Amblyanthera sp., Jan. 1913, Jan. 1925.
Mesechites soalita Vell., Dec. 1915.

ASCLEPIADACEAE.

Oxypetalum sublanatum Malme, Dec. 1915.

BORRAGINACEAE.

Tournefortia sp., Jan. 1925.

VERBENACEAE.

Verbena rigida Spreng., Jan. 1925.
Verbena hirta Spreng., Sept. 1913, Jan. 1925.

CONVOLVULACEAE.

Jacquemontia martii Choisy, Jan. 1925.

LABIATAE.

Salvia sellowinna Benth., March 1914.
Salvia guaranitica St. Hil., Jan. 1913, Jan. 1925.
Salvia coerulea Benth., June 1915.

SOLANACEAE.

Nicotiana langsdorffii Weinm., Jan. 1915, Jan. 1925, e outras occasio.
Cestrum corymbosum Schlecht., Sept.-Oct. 1915, Jan. 1925.
Brunfelsia hydrangaeformis Benth., Jan. 1913, Feb. 1915, Jan. 1925.
Brunfelsia ramosissima, Jan. 1913, Jan. 1925.

SCROPHULARIACEAE.

Herpestes chamaedryoides H. B. K., Jan. 1925.
Verbascum blattarioides Lam., Jan. 1913 Jan. 1925.

BIGNONIACEAE.

Pithecoctenium dolichoides K. Sch., Nov. 19.
Fridericia speciosa.

GESNERIACEAE.

Codonophora prasinata Lindl., Feb. 1915.
Gesnera magnifica Otto et Dietr., April 1912 (also found by Glaziou).
Gesnera maculata Herb., Dec. 1915.
Gesnera cooperi Paxt., Jan. 1913.
Gesnera alagophylla Mart., Jan. 1913, 1925.
Hypocyrta hirsuta Mart., Jan. 1925.

LENTIBULARIACEAE.

Utricularia globulariaefolia Maet., Jan. 1913, 1925, Feb. 1915.

ACANTHACEAE.

Mendozia velloziana Mart., Jan. 1925.

RUBIACEAE.

Coccocypselum condalia Person., Jan. 1925.
Declieuxia polygaloides, Jan. 1913, 1925.
Psychotria rudgeiodes?, Jan. 1925.

CUCURBITACEAE.

Cayaponoa cabocla?, Dec. 1915, Jan. 1925.

CAMPANULACEAE.

Lobelia camporum Pohl., Jan. 1913, Jan. 1925.
Haynaldia hilairiana, Jan. 1925.
Syphocampylus longipedunculatus Pohl., Jan. 1913, Jan. 1925.

COMPOSITAE.

Oligandra lycopoides Less.
Bidens rubifolius H. B. K., April 1915, Jan. 1925.
Wedelia subvelutina D. C., Jan. 1913, Sept.-Oct. 1915, Jan. 1925.
Mutisia coccinea Sr. Hil., Jan. 1913, 1925.
Chevreulia acuminta Less., Jan. 1913, Oct. 1915, 1925.
Gnaphalium sp., Jan. 1913, 1925.
Achillea millefolium L., Jan. 1913, 1925.
Baccharis camporum, Jan. 1913.
Eupatorium sp. (*Symphopappus*), Oct. 1913.
Mikania sessilifolia D. C., April 1915.
Xanthium spinosum Less???, Oct. 1913.

Mikania laevis D. C.
Vernonia tomentella Mart., Jan. 1913, 1925.
Tagetes minuta L., April 1913.
Ambrosia artemisifoliae L., Sept. 1913.
Adenostema sp., Feb. 1915.
Stevia veronicae D. C., Jan. 1913, Feb. 1915.
Erechtites hieracifolia D. C., April 1913.
Achyrocline alata D. C., April 1913.
Eupatorium serratum Soreng., April 1913.
Eupatorium laevigatum Lam., June 1913.
Erigeron maximum Link et Otto, Sept.-Oct. 1913, Jan. 1925.
Hypocheeris Gardneri Baker, Jan. 1913.
Trixis lessingii D. C., Aug. 1913.
Lucilia glomerata, Lucilia lundii, Lucilia acutifolia, Lucilia squarrosa, Lucilia marifolia, Glaziou, 1876.

THE FLUOGERMANATES OF THE UNIVALENT METALS.[1]

By JOHN HUGHES MÜLLER.

(*Read December 4, 1926.*)

Review of the literature of germanium shows that salts of the hypothetical fluogermanic acid, H_2GeF_6, are unknown, with the single exception of the potassium salt which was described by Winkler and used by him in the purification of germanium compounds.[2]

A few years ago the writer had occasion to prepare a considerable quantity of the potassium salt,[3] and at the time noticed that the properties of this compound differed from those behaviors shown in common with other complex salts of fluo-acids of the same type formula, especially those derived from silicon, titanium and thorium. This observation led naturally to the preparation of a complete series of fluogermanates as a means of establishing the relationship which exists between the fluogermanates themselves, and other fluo-salts of the more commonly known elements of the fourth periodic group. In addition to the proposed study of these compounds, much interest and purpose has been added by the kind coöperation of Dr. R. W. G. Wyckoff of the Geophysical Laboratory of Washington, who has undertaken the X-ray spectral analysis of these new crystalline salts. The structures of the potassium and cæsium salts have already been determined and show an interesting dissimilarity existing between them, the former possessing a hexagonal structure and the latter displaying an octahedral habit similar to that of analogous platinum, tin and silicon compounds.

The following communication concerns the preparation and analysis of all of the alkali fluogermanates, including the thallous and

[1] Contribution from the John Harrison Laboratory of Chemistry of the University of Pennsylvania.

[2] Winkler, *J. prakt. Chem. Soc.*, **36**, 177, 1887.

[3] Müller, *J. Amer. Chem. Soc.*, **43**, 5, 1085, 1921.

silver salts of the same acid and also deals with their respective densities, melting points and solubilities.

Reagents and Apparatus.

Lithium Fluoride.—The best obtainable grade of lithium chloride was dissolved in water and poured into an ammoniacal solution of ammonium carbonate. The middle fractions of the precipitated carbonate were selected and were converted to fluoride by action of pure hydrofluoric acid. The precipitated fluoride was thoroughly washed and centrifugally drained.

Sodium Carbonate.—" Baker's Analyzed C. P." sodium carbonate was recrystallized once from water, dried and dehydrated in vessels of platinum.

Rubidium Carbonate.—Commercial rubidium chloride was converted to the alum and the latter double salt fractionated from water solution, until the middle fractions were practically free from cæsium and potassium. The salt was then reconverted to chloride and the solution of the latter fractionally precipitated by addition of chlorplatinic acid. This operation was repeated many times, purposely rejecting first and last fractions, until the flame spectrum indicated the complete absence of cæsium and only traces of the common alkali metals. The chlorplatinate was then decomposed by ignition and the extracted rubidium chloride was changed to sulphate, and finally to carbonate, by the baryta method.

Cæsium Carbonate.—This salt was prepared from a quantity of cæsium alum originally nearly free from rubidium. The alum was several times recrystallized from hot water. The first crops of crystals were converted to sulphate and the latter salt was transposed to hydroxide by baryta and converted to carbonate by carbon dioxide. The carbonate was dehydrated and fused in platinum.

Potassium Carbonate.—Starting with a nearly pure potassium nitrate, the acid tartrate was precipitated and, after thoroughly washing and centrifugally draining, the acid salt was ignited in platinum to the pure carbonate.

Thallium.—Fairly pure metallic thallium was cut into fine turnings and exposed to the action of water and air, until the major portion of the metal had been converted to the hydroxide.. The solution

of the latter was converted to carbonate after filtering out the residua of undissolved metallic particles. Qualitative analysis of the product failed to show any heavy metal impurity.

Silver.—Pure cupel silver was used. The metal was converted to nitrate, precipitated as carbonate, and the washed carbonate was converted to fluoride by dissolving in a slight excess of hydrofluoric acid.

Germanium Fluoride.—Pure germanium dioxide was prepared by the hydrolysis of the redistilled tetrachloride. With the pure ignited dioxide as a starting product, the required amount of fluoride was obtained in each case by weighing out the dioxide equivalent and dissolving in a slight excess of hydrofluoric acid.

Hydrofluoric Acid.—The best grade of concentrated "C. P." acid was redistilled from platinum retort and condenser. The redistilled acid was not stored in bulk but was redistilled in small amounts as required, conducting the distillate into known amounts of the alkali carbonate or germanic oxide and thereby producing the fluorides in known concentration.

Water.—The ordinary distilled water of the laboratory was redistilled in presence of a little permanganate and sulphuric acid, rejecting the first portions of distillate.

All preparations of the various fluorides and their complex salts were carried out in platinum vessels. In filtration and draining operations, funnels and perforated cones of platinum were used.

The purified salts, after dehydration in platinum vessels, were preserved in the dry state in vessels lined with either paraffin or Canada balsam.

Preparation and Analysis of Salts.

All of the described fluogermanates were made by adding the theoretical amount of germanium fluoride in hot aqueous solution to the hot solution of the univalent metal fluoride contained in a large platinum dish. The solutions were made sufficiently dilute to prevent precipitation of the complex salt, for the most part, until the mixtures were cooled. The solutions of the simple fluorides, all slightly acid with excess of hydrofluoric acid, were combined with rapid stirring and the resulting solutions were evaporated until much

of the complex salt crystallized out on cooling. The salts of sodium, potassium, rubidium and cæsium are all far more soluble in hot than in cold water and were comparatively easy to prepare in this way. Yields of these were increased by chilling the solutions to 0° C., filtering off the crystalline masses with centrifugal draining, and then further reducing the volume of the filtrate and re-chilling for second and third yields.

In the case of these four salts the alkali metals were weighed as carbonates, (anhydrous), and subsequently dissolved to the fluoride in slight excess of hydrofluoric acid. The germanium fluoride was prepared in equivalent quantity by weighing out germanium as dioxide and dissolving the latter in slight excess of warm hydrofluoric acid.

The crystalline sodium, potassium, rubidium and cæsium salts were twice recrystallized from hot water, faintly acid with hydrofluoric acid, and again centifuged on platinum cones and dried in air ovens at 130°–140° C. The following yields of purest materials were obtained:

Na_2GeF_6 — 35 g. K_2GeF_6 — 45 g. Rb_2GeF_6 — 30 g.
Cs_2GeF_6 — 50 g.

The fluogermanates of lithium, thallous thallium, and silver are all very soluble salts and much more difficult to prepare in a pure and crystalline condition; hence their preparations are considered under separate headings.

Lithium Fluogermanate.—Lithium fluoride was weighed as such and suspended in cold water. The calculated amount of germanium fluoride, in presence of a slight excess of hydrofluoric acid, was then added and the mixture digested on the water bath until the lithium fluoride had practically all dissolved. After filtration the solution was evaporated to small volume and then chilled to 0° C. As the saturated solution of lithium fluogermanate holds 53.9 g. of the salt per 100 g. of solution at 25° C., it will be seen that this salt is about twenty-seven times as soluble as the corresponding sodium compound at ordinary temperature. The crystalline mass obtained by chilling the concentrated solution was recrystallized from water containing an excess of hydrofluoric acid. It was soon found that this salt could not be heated much above 100° C. without partial decomposi-

tion, with evolution of hydrofluoric acid and some germanium fluoride, as the heated salt failed to completely dissolve in water, leaving a residue of insoluble fluoride. Dried at 80–90° however, the salt appeared to remain unchanged but required some eight to ten hours to arrive at contant weight. When dried, lithium fluogermanate volatilizes rapidly without melting at 400° C., in which respect it differs from all of the other alkali salts of the same acid. The crystalline form of the salt does not appear to be the same as that of any of the other alkali fluogermanates and the crystals first separating seem to be hydrated. Both of these observances are uncertain at present but merit further consideration.

Thallous Fluogermanate.—The thallous salt resembles the lithium compound so far as its solubility is concerned; that is to say, it is too soluble in water to admit of easy crystallization. It was made by combining the calculated quantities of the simple fluorides in hot solution, in the presence of a slight excess of hydrofluoric acid.

The stock of thallous fluoride was dissolved to known volume and the concentration of an aliquot portion was determined by the chlorplatinate precipitation method, while the germanium fluoride required to form the complex fluoride was prepared as in the above described preparations. Care was exercised to mix the fluorides in very exact proportions, so that the mother liquor from the first crop of crystals obtained must have contained little else than the nearly pure salt and the excess of hydrofluoric acid. The crystals which separated on evaporating the solution were large and colorless and exhibited a beautiful pearly luster. Supersaturated solutions were easily obtained, from which masses of the crystalline salt appeared on inoculation with a minute fragment of the solid phase. The first yields of crystals were combined and twice recrystallized from pure water. Thallous fluogermanate is quite heavy (specific gravity 5.906) and melts at 465° C. The yield of pure salt was about 30 g.

Silver Fluogermanate.—The aqueous solutions of the simple fluorides were prepared from weighed amounts of metallic silver and germanic oxide respectively, and the fluorides in aqueous solution were mixed in the calculated ratio to produce the complex salt. The mixed solutions, upon concentration to small volume on the water bath in presence of a little free hydrofluoric acid, gave an oily liquid,

which upon cooling suddenly solidified to a colorless crystalline mass. The solid when heated to 80° C. or slightly above, remelted to a colorless liquid, which, when cooled slowly, remained in the supercooled liquid state for some time. This whole mass became almost instantly solid when stirred or when touched with the solid phase. After removal of all or nearly all of the free acid at 80–90° C., the salt remained completely soluble in very little cold water, but the neutral solution, on standing for some hours, deposited a small black precipitate which contained practically nothing but metallic silver. A solution in water containing a little free hydrofluoric acid, however, appears to remain unchanged on long standing.

Recrystallization of this silver salt requires a large amount of the initial material, as a solution weighing 100 g. carries as much as 88.03 g. of dissolved salt at 25° C. The crystals finally obtained by evaporating the concentrated solution in vacuo over sulphuric acid were large, colorless prisms, and when dry could be heated above the melting point of 80° C. without decomposition. Above 100° the molten compound slowly darkens and on subsequent treatment with water leaves a residue of nearly black metallic silver.

Analysis of Fluogermanates.

As is well known, the usual method for the decomposition and analysis of complex fluorides of the type Me_2RF_6 consists in the treatment of the salt with an excess of concentrated sulphuric acid, whereby hydrofluoric acid is expelled and the nonvolatile residue contains the univalent metal sulphate and the oxide of the acid-forming element. This general method is, however, not at all applicable to any of the fluogermanates above described. Such treatment of these compounds results in loss of fluogermanic acid itself or of germanium fluoride, which escapes with the acid vapors at the fuming point of sulphuric acid. Proof of this peculiarity on the part of the alkali fluogermanates consisted in treating them with sulphuric acid and passing the volatile products obtained by heating to fuming through a platinum condenser tube. All of these salts gave white sublimates even below 300° C., which upon treatment with water and excess hydrochloric acid gave solutions from which germanium sulphide was obtained by action of hydrogen sulphide. The presence of

fluorine was also proved by the glass etching test, which the hydrochloric acid solution of the same deposits gave when such solutions were sealed in glass tubes and allowed to remain in contact with the same at 100° C. for some hours.

After numerous unsuccessful attempts to obtain complete analyses of the alkali fluogermanates, the following method was found fairly accurate. The weighed salts were treated with a little concentrated sulphuric acid and were then carefully heated with the addition of several cc. of fuming nitric acid. The oxides of nitrogen and oxygen escaping from the decomposing nitric acid very slowly, but completely, remove the hydrofluoric acid at a temperature below the point of volatilization of germanium fluoride or fluogermanic acid, and the residue then contained on final heating to fuming—germanic acid and the alkali sulphate. The residues were then taken up in water and the solutions, after rendering about six normal with hydrochloric acid, were treated with hydrogen sulphide to saturation under pressure. The germanium sulphide so precipitated was in each instance converted to dioxide in the usual way and was weighed as such. The strongly acid filtrates, containing much hydrochloric acid and the original small excess of sulphuric acid, were simply evaporated to dryness and the alkali metal sulphate so recovered was weighed in the anhydrous condition.

Another scheme for partial analysis of any of the alkali fluo salts consisted in heating the weighed salt in a platinum crucible in a stream of hydrochloric acid gas. This method, while it gave only the alkali chloride, with loss of both germanium and fluorine, had the advantage of simplicity and high accuracy for the alkali metal content of the salts in question.

Analysis of the thallous and silver salts. The thallous salt was decomposed in the same manner as the above, by frequent treatment and evaporation with a mixture of fuming nitric and sulphuric acids, and the germanium was separated from thallium by precipitation of germanium as sulphide from a solution strongly acid with sulphuric acid. The sulphide of germanium at first thrown down was impure and discolored, due to co-precipitation of some thallium. This yellowish sulphide was treated with ammonia, and hydrogen sulphide was passed in until a small residue of black thallium sulphide re-

mained and all of the germanium sulphide had formed the soluble thiogermanate. The germanium was recovered from the filtrate by strongly acidifying with sulphuric acid and precipitation as before, from six normal acid solutions, as sulphide. The small residue of thallium sulphide was added to the main bulk of thallium sulphate and the solution was evaporated to expel nearly all of the sulphuric acid. The metal was recovered as sulphide, which was in turn converted to chloride and the thallium finally estimated as chlorplatinate.

The silver salt was also decomposed by sulphuric and nitric acids. The residue, which was completely soluble in strong ammonia water, was treated with hydrogen sulphide until the alkaline liquid was nearly saturated with the gas. The silver sulphide which separated was filtered off and, after retreatment with more ammonium sulphide, was converted to chloride in the usual way. The thiogermanate filtrate was treated as before described and the germanium finally weighed as dioxide.

Results of analyses appear in the table which follows.

TABLE I.

ANALYSES OF UNIVALENT METAL FLUOGERMANATES.

Li_2GeF_6.

Analysis.	Per Cent Lithium.	Per Cent Germanium.	Per Cent Fluorine.
1.	6.99	35.08	57.93
2.	7.12	35.94	56.94
Theoretical.	6.92	36.18	56.90

Na_2GeF_6.

Analysis.	Per Cent Sodium.	Per Cent Germanium.	Per Cent Fluorine (by Difference).
1.	20.01	30.91	49.08
2.	19.98	30.89	49.13
3.	——	30.88	——
4.	——	30.95	——
Theoretical.	19.78	31.10	49.12

K_2GeF_6.

Analysis.	Per Cent Potassium.	Per Cent Germanium.	Per Cent Fluorine (by Difference).
1	30.01	27.95	42.04
2	29.95	27.32	42.73
3	29.98	27.49	42.53
Theoretical	29.54	27.39	42.07

Rb_2GeF_6.

Analysis.	Per Cent Rubidium.	Per Cent Germanium.	Per Cent Fluorine (by Difference).
1	48.01	20.51	31.48
2	48.00	20.96	31.04
Theoretical	47.81	20.29	31.90

Cs_2GeF_6.

Analysis.	Per Cent Cæsium.	Per Cent Germanium.	Per Cent Fluorine (by Difference).
1	58.78	16.24	24.98
2	58.72	16.19	25.09
Theoretical	58.75	16.03	25.22

Ag_2GeF_6.

Analysis.	Per Cent Silver.	Per Cent Germanium.	Per Cent Fluorine (by Difference).
1	49.89	19.00	31.11
2	52.99	18.52	28.49
Theoretical	53.65	18.02	28.33

Tl_2GeF_6.

Analysis.	Per Cent Thallium.	Per Cent Germanium.	Per Cent Fluorine (by Difference).
1	——	11.94	——
2	——	12.41	——
3	67.76	——	——
4	67.80	——	——
5	68.20	12.02	19.78
Theoretical	68.63	12.19	19.18

From the above analytical data it will be evident that the fluogermanates which were analyzed all conform to the expected type formula— R_2GeF_6, although in a number of cases the deviation from the theoretical percentage values is larger than that which is to be desired. It is altogether probable that the salts themselves were far purer than their respective analyses would indicate, owing to the method of preparation, and that the errors introduced are largely owing to imperfection in the analytical method. It should be stated, however, that the determination of germanium and an alkali metal in presence of fluorine is a quite difficult problem and that the procedure outlined is the first reported attempt to make this separation and is simply preliminary to a closer study of the problem involved.

In evidence of the purity of the potassium salt, for example, it was observed that the simple decomposition of the salt by ignition in a stream of hydrochloric acid gas gave values for the potassium content of the compound which were very close to the calculated amount of the alkali metal. Three analyses made in this way gave the following percentages for potassium: 29.48; 29.60; and 29.61 (theoretical = 29.54 if Ge = 72.5). This method is certainly much better for the alkali metal content, but was objectionable on account of the resulting loss of germanium and fluorine in an unrecoverable mixture with the excess of hydrochloric acid gas.

Specific Gravities and Melting Points.

Determinations of the densities of the fluogermanates were made through the use of pure toluene, which had been redistilled at constant boiling point (110–111°) and dehydrated by redistillation over metallic sodium. A 25 cc. pyknometer was used and comparatively large samples of the various salts were taken for each determination (10–15 g.). Results were obtained at 25° C. and refer to water at the same temperature.

Melting Points.—Melting points were obtained by the cooling curve method, using 5 to 10 g. of the salt, which was melted in a platinum crucible and allowed to cool slowly in a jacket of non-conducting material. A platinum-platinum-rhodium thermo couple was used, which had been previously calibrated by the cooling curves of bismuth, lead, zinc, antimony and silver. The probable error in temperature reading was ± 2° C. See Table 2.

TABLE 2.

SPECIFIC GRAVITIES AND MELTING POINTS OF FLUOGERMANATES.

Salt Formula.	Specific Gravity. D_{25}^{25}.	Melting Point. C°.	Remarks.
Li_2GeF_6	3.412	——	Rapidly volatilises without melting at 400°.
Na_2GeF_6	3.055	623°	Quite volatile at 750–800°.
K_2GeF_6	3.198	735°	Boils at about 835°.
Rb_2GeF_6	3.891	760°	Quite volatile at 800°.
Cs_2GeF_6	3.899	727°	Slowly volatile at 850°.
Ag_2GeF_6	3.920	80°	Slowly decomposes above melting point, darkens.
Tl_2GeF_6	5.906	465°	Slowly decomposes above melting point.

From the above table it will be seen that the densities of the alkali fluogermanates are not very widely varient and that the lithium salt is unexpectedly of greater density than either the sodium or potassium analogue. This appears to be connected with other points of dissimilarity between the lithium salt and the salts of the common alkali metals.

The cæsium salt shows a melting point which places it between sodium and potassium fluogermanates, instead of the expected position, in which it would follow the rubidium compound. This anomalous behavior is in remarkable agreement with the abnormal solubility of the cæsium salt, in which it falls between sodium and potassium instead of following rubidium as would naturally be expected. (See Table 3.)

SOLUBILITY OF THE FLUOGERMANATES.

Solubility determinations were made according to the method recommended by Findlay ("Practical Physical Chemistry"). In general, the various salts were dissolved in hot water and allowed to cool to near the required temperature, with consequent deposition of the large excess of dissolved salt. This was carried out in platinum dishes and the supernatent liquid, together with some of the suspended solid phase, was then poured off into the suitable container for preservation in the thermostat. The solutions were vigorously stirred for periods of thirty-six hours or more—at a constant temperature of

$\pm$ 0.05°—before samples were taken for analysis. Samples were weighed in a platinum bottle (stoppered), and afterwards evaporated to dryness and gently ignited and weighed in a platinum dish.

The lithium salt, however, could not be treated in this way, as it could not be rapidly dehydrated without some decomposition. This salt appears to carry down some water, and heating even to 100° caused some loss of hydrofluoric acid. In consequence, it was slowly dried to constant weight at 80–90° in a water jacketed oven.

The very soluble silver salt was difficult to deal with, as it melts at 80° C. and at that temperature is soluble in water in all proportions. Dehydration of this salt was very slow, requiring many hours at 60–70° in the absence of light, followed by exposure in vacuo over sulphuric acid for several days before constant weight could be obtained.

The following table shows the results obtained for all of these salts and is accompanied by the solubility curves of the four alkali fluo salts of lesser solubility.

TABLE 3.

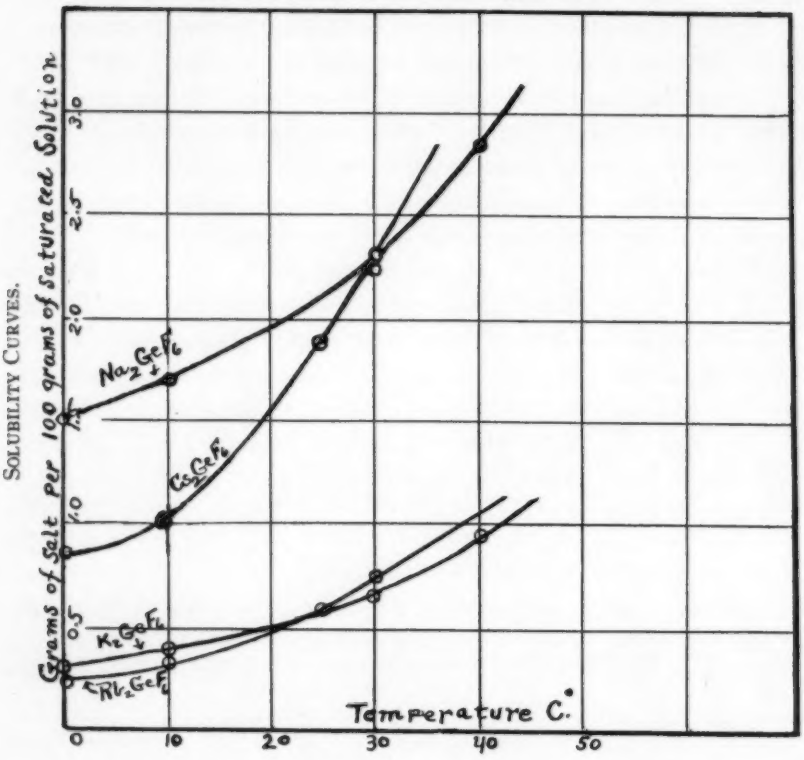
SOLUBILITIES OF THE UNIVALENT METAL FLUOGERMANATES EXPRESSED IN GRAMS OF SALT PER 100 CC. OF SATURATED AQUEOUS SOLUTION.

Formula of Salt.	Temperature C°.					
	0°	10°	25°	30°	40°	80°
Li_2GeF_6	——	——	53.92	——	——	——
Na_2GeF_6	1.52	1.68	——	2.25	2.83	3.36
K_2GeF_6	0.25	0.363	0.59	0.65	0.95	——
Rb_2GeF_6	0.23	0.302	——	0.74	——	——
Cs_2GeF_6	0.84	0.98	1.89	2.28	——	——
Tl_2GeF_6	14.13	——	——	34.58	——	——
Ag_2GeF_6	——	——	——	88.03	——	Sol. in all proportions.

The solubility determinations of the alkali fluogermanates show that the cæsium salt possesses an unexpected solubility, which places this compound intermediate between the sodium and potassium analogues. This anomalous behavior is probably connected with the fact that Cs_2GeF_6 is not isomorphous with K_2GeF_6 as revealed by the X-ray spectra of these salts. The potassium salt shows hexagonal symmetry,[4] while the cæsium compound displays an octahedral habit

[4] P. Groth, *Chem. Krist.*, I., p. 486 (Leipzig, 1906).

Solubilities of the Alkali Fluogermanates.



similar to the analogous platinum, tin, and silicon compounds, as shown by the kindness and coöperation of Dr. R. W. G. Wyckoff of the Geophysical Laboratory at Washington. The results of this investigation will appear in a separate publication, under the title "Crystal Structure of Cæsium Fluogermanate" (Wyckoff and Müller, *Amer. J. Sci.*, April, 1927).

As before indicated, the abnormally low melting point of Cs_2GeF_6 (727° C.), also places cæsium between sodium and potassium in the same series of salts (see Table 2).

The fluogermanates of lithium, silver, and thallous thallium are all very soluble in water. They all three tend to form highly concentrated supersaturated solutions and differ considerably from the sodium, potassium, rubidium and cæsium compounds (see Tables 2 and 3).

The alkali metal fluogermanates in aqueous solution fail to give any precipitation of germanium sulphide, when such solutions are saturated with hydrogen sulphide either in neutral solution or in presence of free hydrofluoric acid. This stability toward hydrogen sulphide, which indicates the firmly bound nature of the fluogermanic acid radical, has already been made the basis of a separation of germanium from arsenic; for hydrofluoric acid solutions of arsenious oxide may be quantitatively precipitated by hydrogen sulphide, leaving all of the germanium in the filtrate as fluogermanic acid.[5]

Summary and Conclusion.

1. The fluogermanates of lithium, sodium, potassium, rubidium, cæsium, thallous thallium and silver have been prepared. These salts represent a new group of compounds, as the potassium salt is the only member of the series previously reported.

2. Methods of analysis of these salts are included, together, with determinations of their specific gravities, melting points and solubilities.

3. The somewhat anomalous position of the cæsium salt in reference to the other members of the series, as shown by its melting point, solubility and crystalline form, is of particular interest; for these properties place this salt in a position intermediate between the corresponding sodium and potassium compounds instead of at the end of the series, following the rubidium salt, as would naturally be expected.

4. The preparation of these salts in a pure condition is preliminary to a further study of their crystallographic structures which is made possible by the kindness of Dr. R. W. G. Wyckoff, who has undertaken their X-ray spectral examination.

[5] Müller, *J. Amer. Chem. Soc.*, **43**, 2549, 1921.

AN ECOLOGICAL-ANATOMICAL STUDY OF BEACH VEGETATION IN THE PHILIPPINES.

By RAYMOND KIENHOLZ.

(*Read April 22, 1926.*)

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INTRODUCTION.

The shore line of the Philippine Islands, extending for thousands of miles, includes a variety of habitats affected by a variety of environmental factors. Extensive areas covered by mangrove species occupy the intertidal region in parts of the Islands, while equally extensive areas are occupied by brackish swamps in which the nipa palm is the predominant species. At other places many miles of level sandy beach occur, or great stretches of rocky cliffs come down to the water's edge. Many small islands are composed wholly of sand and rise only a few feet above sea level, almost free of vegetation or covered with a heavy growth of shrubs and trees forming the "beach jungle" characteristic of the Indo-Malayan region. Usually, however, the shore line of any given area is composed of all of these vegetational types and physiographic areas combined, no one of them being great in extent and yet each showing most of the features found on the more extensive areas.

With such a diversified shore line of muddy flats, sandy beaches, and rocky headlands, in protected bays or exposed to the diverse winds, currents, and wave action of the Pacific Ocean, the China Sea, the Sulu Sea, the Celebes Sea and other smaller seas, gulfs, and channels, subject to a varied rainfall and backed by the varied vegetation of the island's interior, the vegetation typical of these beaches proves to be composed of a large number of species of unusual interest from an ecological and an anatomical viewpoint. Merrill (22) in his "Enumeration of Philippine Flowering Plants" lists 258 species (exclusive of the orchids) as occurring usually along the seashore or along tidal streams, and of this number 33 per cent are endemic to the Philippines. This is an unusually high percentage of endemism when one considers the very wide, often pantropic, distribution of most of the beach species. Merrill (21) states that the percentage of endemism for all the plants found in the Philippines is 40 per cent, of which the species found in the virgin forests have an endemism of 60 per cent or more, while the plants of the thickly populated regions have an endemism of only 18 per cent. The total number of plants found on the beach would be materially increased, if those species are included which occasionally occur along the seashore, and if we included the ferns and the orchids.

In spite of this interesting diversity, little has been done in the Philippines to investigate the vegetation of the beach. An exception to this is to be found in the case of the mangrove and nipa swamps, which have always aroused the interest of the botanist, and in the Philippines have been studied largely because of their economic value. Whitford (32) in a study of the "Vegetation of the Lamao Forest Reserve" discusses the beach vegetation on that part of the Reserve bordering on the sea, where he finds a "dilute expression" of the vegetational types characteristic of the beaches of the Philippines. Based on the physiographic forces at work forming these habitats he recognizes: (1) Sandy beaches lying above high tide, populated by the *Ipomoea pes-caprae* formation and the *Barringtonia-Pandanus* formation; (2) Strand lying below high tide, populated by the Mangrove and *Nipa* formations.

Copeland's (9) ecological study of the San Ramon *Polypodiaceae* includes a few species found along the strand. These he compares

anatomically with the ferns of other habitats and in relation to the severe xerophytic conditions under which they live. Brown (5) in "Minor Products of Philippine Forests" discusses the mangrove swamps of the Philippines, their distribution and the species that characterize them. This work together with the work of Areschoug (1), Karsten (20) and others, makes it unnecessary to discuss this interesting feature of Philippine shore lines. Likewise the nipa swamps which are discussed by Brown and others are omitted from this study.

The classical work of Schimper (27) on the beach vegetation of the Indo-Malayan region will always serve as the basis for any work done in this region. Schimper, however, does not discuss the ecological anatomy of the sandy beach species nor pay particular attention to the vegetation of rocky cliffs fronting on the sea.

Area Covered.

The area to which particular reference is made in this paper is that near the town of Puerto Galera, located on the northern coast of the island of Mindoro. This island, the seventh largest in the Philippines, with an area of nearly 4,000 square miles, is comparatively little known. It is very mountainous, practically the whole interior being a chain of mountains extending from one end of the Island to the other. These mountains extend in spurs and ridges down to the coast, where they terminate in rocky headlands or promontories, alternating with low valleys which form sandy or muddy beaches depending on the amount of sediment brought down by the rivers and on the strength of the wave action and the currents in carrying this material away. The town itself is located at the narrow neck of land where a long, narrow, hilly, indented cape joins the mainland. This cape extends several miles out into the Verde Island Passage and is open on its eastern side to the currents, the wave action and the winds which sweep up this channel from the east. Its western side is protected by a number of small islands, separated by narrow channels, thus forming a comparatively shallow protected bay between them and the main cape. This protected bay with its many identations provide a series of sandy beaches, muddy flats, and rocky cliffs, within a small area, all of which are protected from direct contact

with wave and current action, while the eastern side of the cape affords a similar series open to the stronger action of the elements of the Passage, though not exposed to the open sea. Here we find all of the types of beach vegetation characteristic of the Islands except the nipa swamp. They are all on a small scale, but characteristic nevertheless, as regards species and environmental factors. All of the vegetation on the hills of the cape and some of it directly back of the beach has been altered by man, but very little of the beach vegetation itself has been removed or changed. The exceptions to this are the removal of some of the mangrove trees for tan bark or for firewood, and in a few cases the planting of coconut groves close to the beach and the consequent clearing away of all of the native vegetation.

Back of the town the land gradually rises to the coastal range of mountains about 2,500 feet in height. Many streams, all of them small, drain from these coastal mountains into the sea. Those streams draining directly onto the open coast where the currents and the wave action are strong form level sandy beaches, the stream sometimes being temporarily dammed at its mouth by a sand bar raised by wave action. Those draining into the sea at protected places, particularly into the protected bay to the west of the cape, form low, level sand, or mud flats, on which the mangrove species grow abundantly. The ridges from the coastal mountains end abruptly in rocky headlands of varying heights as they reach the sea. These ridges alternate quite regularly with the sandy beaches or with the muddy flats. Some of these rocky cliffs are composed of a sandstone rock which easily disintegrates into a fine sand, while others are composed of a much harder rock of volcanic origin. Frequently their seaward sides are not so steep but that they are partially or entirely covered with soil. At the foot of these rocky headlands there is frequently a narrow sandy beach, or a sandy beach thickly strewn with boulders, depending on whether the rocks of the cliffs are of sedimentary or of volcanic origin.

Because of the very wide and uniform distribution of most beach plants and because of the uniform environmental factors obtaining on the beach, the types of beach vegetation of this Puerto Galera area are fairly representative of beaches throughout the Islands. Dependent to some extent on the current rainfall, the vegetation of the rocky

cliffs and to a lesser extent that of the sandy beaches has a seasonal periodicity of vegetative activity coincident with the periodicity of the rainfall. As the seasonal distribution of the rainfall varies from a uniform rainfall the year round on the eastern coast of some of the islands, to a decided alternation of dry and wet season on the west coast of most of the islands, the seasonal appearance of the beach vegetation varies somewhat in different localities. However, this variation in rainfall probably does not affect the type of vegetation, nor the floristic composition of the vegetation found on the sandy beach in different parts of the Islands.

Work Done.

During the summer of 1923, the author made a trip through the southern islands of the Archipelago, stopping at many places to make observations and collections of the beach flora. The summer of 1924 was spent at Puerto Galera, where intensive collecting of material and the measuring of environmental factors were carried on as teaching duties permitted. Herbarium material was gathered, particularly of beach species; anatomical material, chiefly leaves, was collected and preserved and readings were taken on evaporation in various habitats, on wind movement, on temperature and on other factors. Observations were made on the distribution of various beach species and a considerable study made of the leaf structure of the beach plants, from fresh material cut with the sliding microtome and cleared with chloral hydrate or stained with various reagents, particularly chlorzinc iodide. This study of the fresh material was especially useful in making stomatal counts and in distinguishing chlorophyll-bearing cells from water storage tissue. The preserved anatomical material has since been sectioned and examined and the data obtained incorporated with that obtained from the fresh material.

The herbarium material has been determined by Dean Elmer D. Merrill of the University of California, to whom my sincerest thanks are due. The plant names used throughout this paper are those recognized by Merrill in his "Enumeration of Philippine Flowering Plants," hence no authorities nor synonyms are given.

Environmental Factors of the Area.[1]

Temperature on the sandy beach during the period of April to June as measured by Standard Weather Bureau thermometers averaged: maximum 88.6° F., and minimum 75.8° F.

Relative humidity on the beach was found to be very high even during the hottest days of the summer season, often being above 80 per cent at such times.

Evaporation was measured by standardized Livingston white spherical atmometers on a rocky headland, on the sandy beach and under the mangrove; the amount of water evaporated at these stations being in the ratio of 100, 58, 33. The constant wind on the rocky headland greatly increased the amount of evaporation.

Sunshine was not recorded beyond general notations on the clearness or cloudiness of the sky. The number of bright clear days was high and this together with the temperatures and almost constant wind movement produced a severe condition for plant life, particularly with regard to water loss from the plant.

Rainfall is fairly uniform throughout the entire year, with the driest months being February and March (about 2 inches per month). Increased precipitation in April, May and June reaches 6 or 7 inches per month, the total annual rainfall being over 53 inches.

Vegetation of the Beach.

The vegetation found along the shoreline of the Philippines may be divided into two distinct types based on the physiographic features of their habitat, namely: (1) that above high tide level and (2) that below high tide level. The area along the seashore which is above high tide level may consist of sandy beaches, rock strewn beaches or rocky cliffs extending up from the water's edge. The area below high tide level is made up of coral reefs, sandy flats or muddy flats submerged at high tide and characterized by the presence of mangrove and nipa swamps, those great " forests of the sea " which have received so much attention from botanists who have visited the tropics. These have received classic treatment at the hands of Schimper

[1] A fuller discussion of the environmental factors of this area and of the beaches of the Philippine Islands in general will be published later in the *Philippine Journal of Science.*

(27), Karsten (20) and others. In deeper water we find the marine vegetation, made up of algae and marine phanerogams.

Marine Vegetation.

The marine vegetation of Puerto Galera and of the Philippine Islands generally consists of two types: (1) the algae and (2) the marine phanerogams. The larger algae are few in individuals and few in species, as is characteristic of most tropical seas when compared to the abundant wrack and kelp beds of our north temperate sea coasts. A few species of *Halimeda,* a calcareous alga, may be found on the firmer sandy floors in shallow water or more likely on coral reefs covered with sand. *Laurencia* and *Caulerpa* are also found to a limited extent. Along muddier shores characterized by a sandy or rocky bottom covered by a layer of mud silt brought down by the rivers we find a considerable growth of *Sargassum* and *Padina.* Along clean sandy shores with a somewhat pebbly bottom we find much of the sea lettuce, *Ulva.*

The marine phanerogams are present in much greater abundance than are the algae and at low tide we find extensive flats of a sandy, slightly muddy or rocky character which, when not exposed to strong wave action, are covered with a growth of various marine phanerogams. The most conspicuous and extensive of these beds are composed of an almost pure growth of *Thalassia hemprichii.* In deeper water we find small beds or clumps of the very rank, coarse-growing *Enhalus acoroides,* which seems to prefer a slightly muddy bottom to a clean sandy bottom. *Diplanthera uninervis* is confined almost exclusively to a clean coral sand bottom, where it unites with *Halophila ovalis* to form dense beds which bind the sand so firmly that at their shallow edges, where wave action has broken up this "sod" of plants, one steps down off the bed eight to ten inches onto the sand which is being carried away by the waves and currents. *Cymodocea rotundata* forms extensive beds, seeming to prefer clean sandy bottoms, though sometimes being found on muddy sand bottoms. *Cymodocea serrulata* and *Halophila spinulosa* are much more rarely found and seldom form dense beds. These facts hold also for the shores of the coral sand islets of the Sulu Sea, where I have collected marine phanerograms at a number of stations.

Sandy Beach.

The lower sandy beach is usually entirely free of vegetation except as seeds contained in the beach drift may attempt to gain a foothold, only to be submerged or washed away. *Barringtonia asiatica* often attempts to establish itself in this way. In many places even where there is considerable wave action there is a growth of mangrove species in the pure sand bottom often with a strip of water and of sandy shore between the clump of mangrove and the higher shore line. The species found in such places are not the species of *Rhizophora* or *Bruguiera* typical of the mangrove swamps but rather those members which are capable of growing and often do grow on sandy or rocky shores within reach of salt water and which form a transition between the true mangrove swamp and the sandy beach. The species usually found there are: *Avicennia marina* and *Sonneratia caseolaris* forming a considerable growth on the sandy, frequently submerged, beach, and *Agiceras floridum, Lumnitzera racemosa, Scyphiphora hydrophyllacea* and *Excoecaria agallocha* forming bushy growths on the sandy beach infrequently submerged by tides.

Usually, however, the lower sandy beach, where wave action is at all evident, is bare of vegetation except as creepers of *Ipomoea, Wedelia* or *Vigna* may grow down from the upper beach. The middle beach is characterized by a number of very typical creepers such as the pantropic *Ipomoea pes-caprae, Canavalia rosea* and *Vigna marina.* Creeping over and parasitizing the vegetation indiscriminately are tangles of the pantropic strand parasitic member of the *Lauraceae, Cassytha filiformis.* Clumps of *Euphorbia atoto,* widely distributed in the Indo-Malayan region, are found scattered on the middle beach and have their counterpart in the *Euphorbia polygonifolia* of our own coasts. Here, too, we find beds of *Sesuvium portulacastrum* and to a lesser extent *Allmania albida* and *Trianthema portulacastrum.* Many grasses and sedges characterize this part of the sandy beach, the most widely distributed and abundant being *Spinifex littoreus* and *Remirea maritima.*

The upper sandy beach is an almost impenetrable tangle of herbs, shrubs and trees, the creeping forms of which send runners down over the middle and lower beach. The woody-herbaceous plant, *Wedelia*

biflora; the scandent shrub, *Quisqualis indica;* the shiny, fleshy-leaved shrub, *Scaevola frutescens;* the hairy-leaved *Sophora tomentosa;* and the larger, delicate-appearing, amyrillidaceous plant, *Crinum asiaticum* form, with *Pandanus tectorius,* a thicket of the lower growing species. Under this thicket wherever possible the herbaceous plants characteristic of the middle beach are found. This whole mass of vegetation is bound together and to the tree growth characteristic of the upper beach by herbaceous vines such as *Calonictyon album* but more still by woody lianas and scramblers, some of which are very characteristic, such as *Dalbergia candenatensis* and *Caesalpinia nuga.* Other scramblers are *Strychnos luzonensis, Jasmium bifarium* and *J. aculeatum,* and *Finlaysonia obovata,* the last found near brackish water. Some lianas typical of the lowland forest also thrive along the seashore.

The most conspicuous element of the upper beach vegetation is the trees, one of the chief of which is *Barringtonia speciosa* from which Schimper (27) named his *Barringtonia*-formation, though he, in an earlier paper, had named it after *Terminalia catappa,* another common beach tree. Whitford (32) has combined the tree forms with the undergrowth forms, calling the vegetation of the upper beach the *Barringtonia-Pandanus*-formation. The trees mentioned are little if any more abundant, however, than *Thespesia populnea, Sideroxylon ferrugineum* or *Hernandia ovigera. Hibiscus tiliaceus* is very common also, though not at Puerto Galera. Most of these species with their shiny, leathery leaves form what is sometimes called the " beach jungle " or the " beach forest " when extensive in area as it often is on small sandy islands.

Smaller trees common to the upper beach are the hairy-leaved, gnarled, very common *Tournefortia argentea,* the small varnished-leaved *Dodonea viscosa, Opilia amentacea, Tristera triptera, Ximenia americana, Pemphis acidula, Suriana maritima, Pongamia pinnata, Guettarda speciosa* and *Morinda citrifolia.* Occasionally dense thickets of the introduced shrubs, *Prosopis vidaliana* or *Acacia farnesiana* are found on the sandy beach. *Vitex trifolia* forms thickets on the sand of the upper beach and its low growing variety *ovata* forms a dense cover in similar situations.

Heritiera littoralis with its peculiar boat-shaped buoyant fruits,

often found at the back of mangrove swamps, is also present on the sandy beach. *Xylocarpus moluccensis* and the shiny, leathery-leaved *Calophyllum inophyllum* often grow so close to the water's edge as to reach out over the water and receive reflected light from below.

On beaches strewn with rocks one often finds the leathery-leaved *Diospyros maritima* associated with *Avicennia marina* and others.

Rocky Headland.

The vegetation of this physiographic area is largely derived from the sandy beach or from the inland forests and consists of many species of a diverse nature. There are, however, certain plants which are almost always found on the steep cliffs overhanging the sea or on the large rocks and boulders forming the shore. Of these, the most characteristic are epiphytes belonging to the ferns; *Cyclophorus adnascens* on rocks and trees, *Polypodium scolopendium* and the humus collecting *Drynaria quercifolia*. These are able to withstand the dry season and to spring into luxuriance when the rains begin. Certain grasses and sedges also grow on the steep slope of the rocky cliffs, such as *Monerma repens, Panicum carnatum* and *Scleria lithosperma*.

Trees and shrubs likewise are found clinging to the sides of these rocky cliffs wherever a foothold can be obtained. The most common of these are: *Plectronia gynochthedes, Ardisia pyramidalis, Lunasa amara, Gardenia morindaefolia* and *G. merrillii* and *Vitex parviflora*. On certain rather open sloping cliffs *Cycas rumphii* and species of *Pandanus* are found abundantly. The liana *Derris mindorensis* is also found back of rocky shore lines. Herbs and epiphytes form an undergrowth on the steep slopes of cliffs. Two very characteristic and commonly found plants of the rocky cliffs are the leafless vine *Sarcostemma brunonianum* and the milky-juiced *Hoya cummingiana* with its 4-ranked leaves.

At the base of these cliffs may be a sandy or a rocky beach of small extent on which the common sandy beach species are found. On very exposed volcanic rock cliffs low down to the water I have found *Pemphis acidula* growing as a gnarled thick-leaved shrub; *Evolvulus alsinoides* and the grass *Monerma repens*.

Form and Structure of Beach Plants in Relation to Ecological Factors.

The vegetation of the sandy beach and the rocky headland is exposed to severe environmental conditions. These environmental factors may bring about a modification in the form or the habit of the plant or they may modify the structure of the plant parts, particularly the leaves. The form of the plant may be modified in response to the shifting character of the sand upon which some of the beach species grow. In the Puerto Galera region the shifting of the sand by wind is slight because much of the sand is coarse, the damp air and the frequent rains lessen the movement and the rocky headlands protect the sandy beaches from very strong winds. To what extent the plants of the sandy beach are affected by a shifting substratum or by wind blown sand it is difficult to say. I have noted on small wind-swept coral sand islets in the Sulu Sea, *Wedelia biflora* and other similar plants creeping over the sand, nowhere forming the bushy tangle normally so characteristic of *Wedelia*. Whether this creeping habit was an adaptation to excessive wind movement or whether it was due to the intense heat, light, and high transpiration rate, cannot be decided. The fact remains, however, that much of the herbaceous and some of the woody vegetation found on the beach is of a low growing habit.

Ipomoea pes-caprae, Canavalia rosea, C. microcarpa and *Vigna marina* are all herbaceous creeping forms sending runners out over the sand, which sometimes take root. *Wedelia biflora* and *Quisqualis indica* are often low growing forms particularly on the open sandy beach though they also form shrubby growths. Few of the grasses on the beach grow to a great height, while some forms such as *Spinifex littoreus* send out runners which take root to form new plants.

Allmania albida, Trianthema portulacastrum and *Sesuvium portulacastrum* are low growing, succulent, rosette plants, while *Euphorbia atoto* forms small low clumps. *Crinum asiaticum,* on the other hand, is an exception in that it grows to a height of four to five feet but is usually protected by the shrubby growth of *Scaevola frutescens* and *Wedelia biflora.*

Some of the shrubs and trees on the upper beach show signs of the high winds prevalent on the beach by their small gnarled form (*Tournefortia argentea*), and their umbrella-like shape (*Terminalia catappa, Barringtonia asiatica*). When *Scaevola frutescens* grows on small sandy islets it is often low, sprawling and gnarled. The tree growth on the rocky headlands is often dwarfed as a result of wind action. What little mechanical tissue is found in the leaves probably has little effect in protecting the plants against wind-blown sand.

Environmental factors which limit the supply of available water in the soil and make for a rapid loss of that already in the plant, are much more severe and much more potent than are the factors of shifting substratum and wind-blown sand, if we may judge from the large number of structural features which conserve the water supply of the plants found on the beach.

Many of the plants of the sandy beach are deeply enough rooted to have an abundant supply of soil moisture. In the case of mangrove and nipa swamp species and some of the beach trees growing on rocky beaches or at the base of cliffs where their roots are subject to salt water at high tide, the difficulty of water absorption causes a physiological drought which makes it imperative for the plant to conserve its water supply. Some beach plants and especially those of the rocky headlands growing on the exposed faces of the cliffs are dependent on the moisture in a quick draining or in a shallow soil. In spite of an abundance of water in the soil and a high relative humidity of the air the plants must conserve their moisture because of the high rate of evaporation brought about by the conditions enumerated below:

1. One of the most severe conditions under which the sandy beach vegetation and particularly the rocky headland plants must exist is the almost constant and often strong winds. Wind greatly increases evaporation as was evidenced by measurements discussed elsewhere.

2. The comparatively high temperature the entire year makes for a high water loss from the plant particularly when we consider the great heat reflected from the sand on which many of the plants grow.

3. The light of the tropical sun is very intense and when to it is added the reflection from the white coral sand of the beaches and

from the water and the breakers near the shore its effect on the plant must be severe. It not only increases the transpiration but may actually injure the tissue of the leaf itself. Copeland (8) says transpiration in the coconut is increased four times by a change from a light haze to full illumination.

4. The sandy substratum of the beach allows water to drain away or to be lost through evaporation very readily and rapidly, the surface layers drying out quickly.

5. Salt spray is sometimes thrown inland for some distance and the leaves of the beach plants especially are often coated with it. That the presence of this spray has an effect on the vegetation is indicated by Whitford (32) who cites an example of salt spray thrown inland by a typhoon settling on *Terminalia catappa,* a typical strand tree, and on *Artocarpus incisa,* an inland species. The *Artocarpus* was killed by the salt spray while *Terminalia* was unharmed.

6. Some of this salt spray falls on the soil but the investigation of Kearney (19) has shown that sandy beach plants are not halophytes, as the sand is comparatively free of salt. Plants growing in the mangrove and nipa swamps, and those found near enough to sea to be affected by salt water at high tide are true halophytes, however, and in addition to a high rate of water loss they have difficulty in absorbing water.

The presence of these factors of light, heat, and wind which greatly increase the rate of transpiration have brought about many structural features in the plant which tend to decrease the water loss and conserve the water already in the plant. These structural adaptations are noticeable in many of the plant parts but have been examined chiefly in the principal transpiratory organ, the leaf.

The change in the position of leaves during the period of greatest heat and light probably protects against excessive water loss and likewise against injury due to intense light. *Ipomoea pes-caprae* folds its leaves along the midrib with the inner faces together; *Canavalia spp.* and *Vigna* fold their three leaflets together; while *Euphorbia atoto* and *Sophora tomentosa* also have a slight amount of leaf movement to place the former's leaves closer to the stem with the upper side inward or fold the latter's leaflets together.

The total suppression of the leaf as a photosynthetic organ has

occurred in *Cassytha filiformis,* where the leaves are scale-like and protect the bud, the entire photosynthetic function being taken over by the stem. In *Sarcostemma brunonianum,* a frequent inhabitant of the rocky cliffs, the stem has likewise taken over the photosynthetic function.

Reduction in the size of the leaves has occurred in only a few species such as *Pemphis acidula* and *Suriana maritima.*

Thin, slender leaves, standing erect and receiving light on both sides is characteristic of most of the grasses and sedges found on the beach, particularly *Spinifex littoreus* and *Remirea maritima.*

Hairy leaves are abundant but in many cases the hairs are not numerous enough nor sufficiently developed to be a protection. The leaves are arranged in the order in which their hairy coverings are probably effective in reducing transpiration. *Heritiera littoralis* (closely overlapping peltate hairs on lower surface); *Vitex trifolia* (very dense mass of two-celled hooked hairs on lower surface); *Sideroxylon ferrugineum* (large flat hairs forming layer on lower surface); *Tournefortia argentea* (loose tangle of hairs on both surfaces). Hairs are present also in *Sophora tomentosa,* and *Pemphis acidula* but probably have little effect on the transpiration rate.

Waxy bloom on the leaf is found only in the case of *Euphorbia atoto.*

Greatly thickened cuticle and outer epidermal walls are found as follows, arranged in the order of their thickness; *Crinum asiaticum, Sideroxylon ferrugineum, Calophyllum inophyllum, Sophora tomentosa, Vitex trifolia* (upper surface only), *Xylocarpus moluccensis, Glochidion littorale,* and the epidermis of *Cassytha filiformis.* Other species have thickened outer epidermal walls which are cutinized or overlaid with a cuticle but the cutinization is not excessive.

Varnished leaves are especially well developed in *Dodonaea viscosa* and *Scaevola frutescens* and may reflect the light rays, as Wiesner has suggested. Many of the beach trees and especially the mangrove species have shiny leaves and may be classed as varnished.

Sunken stomates are frequently encountered. The species having them are here arranged according to the degree of depression (the figure in parenthesis following each species is the number of microns from the outer surface of the epidermis to the point of closure of

the stomate).[2] *Crinum asiaticum* (30.7), *Glochidion littorale* (30), *Sophora tomentosa,* (28), *Cassytha filiformis* (25), *Sideroxylon ferrugineum* (22), *Pemphis acidula* (18) and *Spinifex littoreus* (18). *Sophora* is probably the most effective as the surrounding epidermal cells overarch slightly to make a rather narrow, deep depression. Three other species have slightly depressed stomates.

Of the 22 species examined 50 per cent have sunken stomates, 41 per cent have stomates level with the epidermis and 9 per cent have raised stomates, these last being *Heritiera littoralis* and *Vitex trifolia;* the very abundant hairs probably act efficiently to prevent the rapid diffusion of the blanket of air of a high humidity immediately surrounding the stomates, hence the raised stomates do not lose water readily.

A hypodermal tissue is present in a number of the species examined. It varies from one to several cells in thickness and may or may not be accompanied by water storage cells. If the sub-epidermal cells free of chloroplastids are thick-walled I have considered them as hypodermis; while thin-walled cells free of chloroplastids I have considered as water storage cells. The hypodermal cells probably function as a strengthening tissue, as a water storage layer and also to reduce the intensity of the impinging light. *Heritiera littoralis, Vitex trifolia* and *Glochidion littorale* have well developed hypodermal layers, while *Xylocarpus moluccensis* has a single thick-walled hypodermal layer, below which is a layer of thin-walled water storage cells.

The abundance of water storage tissue is a striking characteristic

[2] The method here used of indicating the amount of stomatal depression by the number of microns from the general level of the epidermis to the point of closure of the guard cells means that each stomate, even though its outer edge is level with the epidermis or slightly raised, will have its point of closure several microns below the level of the epidermis. This figure varies from 5 microns to 15 microns (average 8.6 microns) for the 10 species whose stomates are level with the epidermis; that is, the outer wall of whose guard cells is level with the general level of the outer edge of the epidermis.

Of even greater importance in retarding transpiration than mere depression of a stomate in a shallow pit, is the length, diameter and tortuousness of the stomatal pore and the kind of vestibular chambers it has. These points can best be noted from the illustrations in Plates II. to VI. Thus the stomates of *Calophyllum inophyllum* (Plate IV.; 15a) are probably more effective in restricting transpiration that those of *Allmania albida* (Plate II.; 3a).

of the species examined. As the leaves become older they increase in thickness and much of this increase is due to an increase in the amount of water storage tissue, as in *Sesuvium portulacastrum*. In some cases, as *Pemphis acidula*, the cells which were chlorophyll-bearing cells in the young leaf become enlarged, the chloroplastids become attenuated or disappear entirely and the cells become wholly water storing in function. Only a few of the beach species can be called succulent. These are: *Sesuvium portulacastrum, Trianthema portulacastrum,* and *Pemphis acidula*. *Allmania albida* should probably be included here also, as its large chlorophyll-bearing cells are very largely water storing. Several other species have an abundance of centrally located water tissue: *Crinum asiaticum, Ipomoea pes-caprae* (sun form), *Spinifex littoreus* and *Tournefortia argentea*. *Wedelia biflora* and *Xylocarpus moluccensis* have water tissue below the upper epidermis while *Euphorbia atoto* has an abundance just above the lower epidermis. Most of the species enumerated above also have colorless parenchyma cells, doubtless storage in nature, around the veins. Only five out of the 22 species examined do not have any water storage tissue.

The arrangement of the chlorenchyma is indicative of the severe environmental factors under which the beach vegetation exists. Whether formed in response to the stimulus of light or some other agency, a leaf mesophyll composed entirely or largely of palisade tissue will transpire less than one made up of sponge tissue, the degree of compactness of either tissue determining the amount of transpiration. The mesophyll of the leaves of *Prosopis vidaliana* and *Vitex trifolia* are composed wholly of palisade, while *Sesuvium portulacastrum, Pemphis acidula, Ipomoea pes-caprae* (sun form) and *Tournefortia argentea* have palisade layers on both sides of the leaf with a water storage layer between. *Sophora* has a palisade above and a very imperfectly developed one below with sponge between. Six other species have a palisade-like development of the cells of the lowest sponge layer. *Trianthema portulacastrum* has a festoon of palisade cells around each vein, so characteristic of succulents, while the chlorenchyma of *Spinifex littoreus* is like a very compact sponge.

Mucilage cells are found in the epidermis and mesophyll tissue

of *Pemphis acidula*, the cortical cells of *Cassytha filiformis*, the mesophyll cells of *Hernandia ovigera;* while in *Thespesia populnea* slime cells are found. *Latex tubes* are found in *Euphorbia atoto*.

Stone cells are infrequently encountered in the leaves studied. *Prosopis* has many spool-shaped stone cells while *Scaevola* has scattering branched stone cells in the mesophyll.

Stereome tissue is developed in a number of the leaves as a mass of cells just above and below the veins or extending in a narrow band from the veins to the upper and lower epidermis. Whatever the function of the stereome, it is a significant fact that the leaves that contain it in the most highly developed form are from the beach tree species which show the greatest xerophytism in their structure. *Prosopis vidaliana, Heritiera littoralis, Xylocarpus moluccensis, Calophyllum inophyllum* and *Sideroxylon ferrugineum* show well developed stereome and *Vitex trifolia, Sophora tomentosa, Thespesia populnea* and *Glochidion littorale* show it poorly developed. The other species show none.

Leaf Anatomy.

The leaves of many species typical of the beach vegetation were gathered at Puerto Galera in 1924 and 1925 during April, May and June, toward the close of the period of least rain. These leaves were gathered from vigorous plants fully exposed to the environmental factors of the beach and in all cases fully mature, but not old, leaves were gathered. These were killed in medium chrome-acetic acid and were imbedded in paraffin in the usual way. They were cut and stained with safranin and light green.

The study of these sections served as the basis for the figures illustrating the structural features of the leaf. Additional information was obtained from a study of many of the leaves from fresh material. The figures represent the typical structure of the leaves in cross-section and are drawn to a scale of 110 with the exception of *Sesuvium* (× 47), *Cassytha*, cross-section of stem (× 66), *Pemphis* (× 66) and *Vitex* (× 266). The stomates are all drawn to a scale of 335 and the structural details are usually drawn to a scale of 110. The species are arranged according to their taxonomic sequence.

The detailed anatomical features of each species examined are discussed below.

TABLE I. SUMMARY OF THE STRUCTURAL FEATURES OF THE LEAF
(+ indicates presence of a character; ± indicates its imperfect development.)

SPECIES	LEAF			HAIRS				UPPER EPIDERMIS			PALISADE					SPONGE					WATER STORAGE TISSUE					STOMATA			LOWER EPIDERMIS	INCLUSIONS			
	RELATIVELY THICK ABOVE 350 μ	SUCCULENT	LEATHERY	UPPER SURFACE ONLY	LOWER SURFACE ONLY	BOTH SURFACES	OUTER WALL PLUS CUTICLE THICK	THICK	HYPODERMIS	ALL OF LEAF	BOTH SURFACES	UPPER SURFACE ONLY	NONE	COMPACT	LOOSE	NONE	COMPACT	LOOSE	MIDDLE OF LEAF OR LOWER SURFACE ONLY	BELOW UPPER EPIDERMIS	MIDDLE OF LEAF	AROUND VEINS	THRU THE LEAF AT VEINS	ABOVE LOWER EPIDERMIS	SUNKEN	LEVEL	RAISED	HEAVILY CUTINIZED	THICK	CRYSTALS	LATEX	MUCILAGE CELLS	STONE CELLS
1 Spinifex littoreus	+						+				±			+			+		+	+	+				+			+					
2 Crinum asiaticum	+						+	+						+			+		+	+	+				+			+					
3 Allmania albida	+	+												+			+		+	+	+				+			+					
4 Trianthema portulacastrum	+	+												+			+		+	+	+				+			+					
5 Sesuvium portulacastrum	+	+												+			+		+	+	+				+			+					
6 Hernandia ovigera			+											+			+		+	+	+				+			+					
7 Prosopis vidaliana			+											+			+		+	+	+				+			+					
8 Sophora tomentosa			+											+			+		+	+	+				+			+					
9 Xylocarpus moluccensis			+											+			+		+	+	+				+			+					
10 Euphorbia atoto			+											+			+		+	+	+				+			+					
11 Glochidion litterale			+											+			+		+	+	+				+			+					
12 Thespesia populnea			+											+			+		+	+	+				+			+					
13 Heritiera littoralis			+											+			+		+	+	+				+			+					
14 Calophyllum inophyllum			+											+			+		+	+	+				+			+					
15 Pemphis acidula			+											+			+		+	+	+				+			+					
16 Sideroxylon ferrugineum			+											+			+		+	+	+				+			+					
17 Ipomoea pes-caprae (sun)			+											+			+		+	+	+				+			+					
17 Ipomoea pes-caprae (shade)			+											+			+		+	+	+				+			+					
18 Tournefortia argentea			+											+			+		+	+	+				+			+					
19 Vitex trifolia			+											+			+		+	+	+				+			+					
20 Scaevola frutescens			+											+			+		+	+	+				+			+					
21 Wedelia biflora			+											+			+		+	+	+				+			+					
Total number	10	5	7	0	3	3	12	8	4	5	12	11	0	21	5	13	9	3	10	4	5	10	4	2	10	10	3	8	1	4	1	3	2
Per cent	45	22	31	0	13	13	54	36	18	22	54	50	0	95	22	100	40	13	76	18	22	76	18	9	45	45	13	36	45	18	45	13	9
22 Cassytha filiformis														All palisade																			

Table 1 summarizes the presence or the absence of those structural features which may be of importance as adaptations to the environment of the beach. One of the most outstanding features of the sandy beach plants is the great thickness of the leaves, averaging

TABLE 2 MEASUREMENTS OF THE LEAF TISSUES
(THICKNESS OF THE TISSUES EXPRESSED IN MICRONS OR IN PERCENTAGE OF TOTAL THICKNESS MINUS DEPRESSION INDICATES STOMATES RAISED)

SPECIES	TOTAL THICKNESS (MICRONS)	CUTICLE AND OUTER EPIDERMAL WALL UPPER	CUTICLE AND OUTER EPIDERMAL WALL LOWER (MICRONS)	UPPER EPIDERMIS AND CUTICLE (PER CENT)	HYPODERMIS (PER CENT)	WATER STORAGE CELLS BELOW EP (PER CENT)	PALISADE (PER CENT)	SPONGE (PER CENT)	CENTRAL WATER STORAGE CELLS (PER CENT)	LOWER SPONGE (PER CENT)	LOWER PALISADE (PER CENT)	LOWER WATER STORAGE CELLS (PER CENT)	LOWER EPIDERMIS AND CUTICLE (PER CENT)	HAIRS (PER CENT)	STOMATAL DEPRESSION (MICRONS)
1. Spinifex littoreus	630	4.0	3.0	4.3	0	71.4	0	20.0	0	0	0	0	4.3	—	18.0
2. Crinum asiaticum	525	12.6	9.0	10.0	0	0	20.0	23.0	14.0	24.0	0	0	9.0	—	30.7
3. Allmania albida	520	3.6	3.6	14.0	0	0	20.0	36.0	0	0	0	0	10.0	—	0
4. Trianthema portulacastrum	400	2.0	2.0	12.5	0	18.0	34.0	0	0	0	0	22.0	13.5	—	0
5. Sesuvium portulacastrum	1980	5.4	3.5	1.5	0	0	15.0	0	0	0	10.0	0	1.5	—	0
6. Hernandia ovigera	297	5.0	3.6	10.0	0	0	44.0	32.0	0	0	6.0	0	8.0	—	12.0
7. Prosopis vidaliana	210	3.7	2.4	7.0	0	0	86.0	0	72.0	0	0	0	7.0	—	10.8
8. Sophora tomentosa	270	9.0	5.4	15.0	0	0	37.0	18.0	0	0	7.0	0	12.0	—	28.0
9. Xylocarpus moluccensis	335	5.5	5.0	5.5	9.0	21.5	31.0	20.0	0	0	0	0	6.0	—	0
10. Euphorbia atoto	320	3.5	4.0	5.5	0	0	61.0	0	0	0	0	26.0	7.5	—	12.0
11. Glochidion littorale	330	4.0	6.0	4.5	10.5	0	30.0	46.0	0	0	0	0	9.0	—	30.0
12. Thespesia populnea	285	3.8	3.4	10.5	0	0	37.0	35.0	0	0	28.0	0	4.5	—	0
13. Heritiera littoralis	275	3.5	3.0	7.3	12.7	0	16.4	48.0	0	0	0	0	3.6	12.0	12.0
14. Calophyllum inophyllum	330	7.2	6.0	8.5	0	0	24.0	51.0	0	0	8.0	0	7.5	—	0
15. Pemphis acidula	1035	3.7	3.0	4.3	0	0	10.0	0	75.0	0	6.7	0	4.0	+	18.0
16. Sideroxylon ferrugineum	325	9.5	6.0	9.0	0	0	41.0	41.0	0	0	0	0	9.0	+	22.0
17. Ipomoea pes-caprae (sun)	785	3.6	3.6	3.0	0	0	19.0	0	36.8	0	38.0	0	5.2	—	0
17. Ipomoea pes-caprae (shade)	260	3.5	3.5	8.1	0	0	25.5	32.0	0	0	24.0	0	10.4	—	0
18. Tournefortia argentea	690	2.7	2.7	3.5	0	0	19.0	0	45.0	0	28.0	0	4.5	+	0
19. Vitex trifolia	200	7.5	2.0	8.0	13.0	0	72.5	0	0	0	0	0	6.5	+	-6.0
20. Scaevola frutescens	515	4.5	2.7	10.3	0	0	49.0	35.5	0	0	0	0	5.2	—	0
21. Wedelia biflora	385	2.5	1.8	5.5	0	14.0	44.5	31.0	0	0	0	0	5.0	—	0
Total number	22	22	22	22	4.0	4.0	21.0	14.0	5	1.0	9	2.0	22.0	—	10.0
Average	495	4.9	3.5	7.6	11.3	31.2	35.0	35.4	48.5	24.0	18.5	24.0	8.18	—	20.6
22. Cassytha filiformis	—		6.3	—	—	—	—	—	—	—	—	—	—	—	25.0

495 microns in the 21 species studied and running up to almost two millimeters in some species. Another feature is the large amount of water storage tissue. Eighty per cent of the beach species I have examined have some form of water storage tissue while Harshberger (15) lists but 20 per cent of his New Jersey sand-strand species as succulent and 50 per cent of his salt marsh species. Kearney (18) finds but 54 per cent of his sand-strand species from Ocracoke Island containing water tissue and 44 per cent of his salt marsh species. If

those species typical of the mangrove were included in my calculations the number containing water storage cells would amount to over 90 per cent.

TABLE 3. NUMBER OF STOMATES PER SQUARE MM.

Species	Upper Surface	Lower Surface	Total
Heritiera littoralis	0	448	448
Hernandia ovigera	0	383	383
Scaevola frutescens	0	324	324
Vitex trifolia	0	260	260
Sideroxylon ferrugineum	0	225	225
Xylocarpus moluccensis	0	200	200
Thespesia populnea	0	188	188
Glochidion littorale	0	185	185
Calophyllum inophyllum	0	156	156
Sophora tomentosa	0	102	102
Spinifex littoreus	0	102	102
Wedelia biflora	9	332	341
Crinum asiaticum	14	69	83
Allmania albida	73	118	191
Ipomoea pes-caprae (sun)	127	123	250
Ipomoea pes-caprae (shade)	97	98	195
Pemphis acidula	48	46	94
Trianthema portulacastrum	99	83	182
Prosopis vidaliana	170	108	278
Tournefortia argentea	40	23	63
Sesuvium portulacastrum	60	35	95
Euphorbia atoto	223	45	268
Cassytha filiformis	---	---	81
MANGROVE SWAMP SPECIES			
Rhizophora candelaria	0	97	97
Scychyphora hydrophyllacea	0	102	102
Agiceras sp.	0	105	105
Rhizophora mucronata	0	123	123
Sonneratia caseolaris	87	62	149

Table 2 indicates the total thickness of the leaf expressed in microns and the thickness of the tissues of the leaf expressed in percentage of the total leaf thickness. Wherever the thickness of the outer epidermal wall is spoken of, the outer epidermal wall plus the

cuticle is referred to, unless only the cuticle is specifically mentioned. In referring to the degree of elevation or depression of the stomates I have measured from the point of closure of the guard cells to the general level of the outer surface of the epidermal cells. This seemed more logical than measuring only to the outside of the outer cuticular ridge, as this often closes very imperfectly or not at all.

Table 3 arranges the leaves in the order of the abundance of their stomates per square millimeter, a few typical mangrove species being included for comparison with sandy beach species.

Spinifex littoreus (Plate I., Fig. 1; Plate II., Figs. 1, 1*a*, 1*b*).

This very widely distributed grass is found on the sandy beach from near the water's edge to far back upon the beach. It prefers beaches of fine sand and in such habitats it sends its characteristic runners in all directions, taking root and producing masses of spear-like leaves. It forms dense masses wherever it is found, and it is usually associated with various beach sedges and grasses as well as with *Ipomoea* and *Canavalia*.

Its erect leaves are stiff and sharp, in cross-section forming a broad U- or sharp V-shape, very thick at the midrib and tapering toward both edges. The entire upper (ventral) part of the leaf is a mass of *water storage cells* protected by an *epidermis* of fairly large cells, the outer walls of which are cutinized but the lateral and inner walls of which are thin and of cellulose. The *chlorenchyma* tissue forms a band of uniform thickness just inside the *lower* (*dorsal*) *epidermis,* hence the water storage tissue is most abundant at the midrib and tapers to nothing at the edges. The *veins* (large and small alternating) are all arranged near the lower epidermis and are imbedded in the chlorenchyma. The *parenchyma sheath* surrounding the bundles is thicker walled than are the chlorenchyma cells but contains chloroplastids, chiefly on the side next to the chlorenchyma. The *mestome sheath* is imperfectly developed and its walls are only moderately thick. *Xylem* and *phloem* cells are well developed and additional *stereome* cells are found above and below the xylem and phloem. The *lower epidermal cells,* especially the outer wall but also the lateral and inner walls, are heavily cutinized. Opposite the larger bundles the epidermal cells are much smaller than elsewhere,

and abutting on these smaller cells is the *sub-epidermal stereome,* made up of varying number of thick walled cells which extend to the parenchyma sheath of the vein. The *stomates* are located almost entirely on the lower surface (102 per square millimeter), but a few are found on the upper surface near the edge of the leaf. They are sunken (18 microns) below the general level of the epidermis. They are of the characteristic grass type, the guard cells being very thick-walled, the lumen having almost disappeared. The subsidiary cells are entirely uncutinized. The edges of the leaf are also provided with stereome cells. On the upper surface near the edge are one or two masses of poorly developed *bulliform cells* though none are located near the midrib.

Crinum asiaticum (Plate II., Figs. 2, 2*a*).

This amyrillidaceous plant with its large leaves grows on the upper beach with *Scaevola, Wedelia,* and *Sophora,* and likewise it may be found within or at the edges of mangrove swamps, or along brackish streams. It frequents the more open type of mangrove swamp which borders brackish rivers rather than the dense mangrove swamp formed by the typical mangrove species. Its fruits are often cast up on the beach by waves. Its leaves are large, linear, and thickened to a heavy midrib full of large air chambers.

The leaf structure of specimens growing on the sandy beach shows an *upper epidermal layer* of large, even-sized cells overlaid with a heavy *cuticle* (4.5 microns) especially thickened where the lateral walls join the outer walls. A single layer of short broad *palisade* cells is followed by several layers of rather loose *sponge cells.* A varying amount of *water storage tissue* is found in the center of the leaf below which are several layers of very open *sponge cells.* The *lower epidermis* is also heavily cutinized, the cells being papillate with from one to several papillae. This gives the epidermis a very wrinkled appearance in surface view. The *stomates* are large and few in number being seventy per square millimeter on the lower surface, and fifteen per square millimeter on the upper surface. They are most abundant on either side of the veins and are few in number or almost absent from over the veins and from between the veins. (They are all placed with their long axis parallel to that of

the leaf.) The cuticle forms two very prominent horn-like projections on the outer edge of the guard cells and some cutinization is also evident in projections on the inner edges of the guard cells. The stomates are sunken (30.7 microns) below the surface. *The veins* are few in number and widely separated, the *xylem* elements being poorly developed. Each vein is surrounded by an abundance of water storge cells but there is an entire absence of *stereome* cells.

Allmania albida (Plate II., Figs. 3, 3*a*).

A prostrate plant with lanceolate, rather succulent leaves. Merrill reports it only from Mindoro in the Philippines though it is distributed along the sandy seashores of India, Ceylon to Java.

Its medium thick leaves show few xerophytic structures beyond a slight *cuticle* on the upper and the lower surfaces and a succulency which probably acts as a xerophytic adaptation. One layer of large *palisade cells* is followed by several layers of rather loosely laid *sponge*. The cells of the palisade and sponge tissues are all large with sparse chloroplastids and they probably act as *water storage cells* as well as photosynthetic cells. The lateral walls of the *upper epidermal cells* are straight while those of the *lower* epidermal cells are wavy. The *stomates* are quite large and are found both on the upper (73 per square millimeter) and the lower (118 per square millimeter) surfaces of the leaf. They are level with the epidermis. The *veins* are very small, few in number and are free of *stereome* cells.

Trianthema portulacastrum (Plate II., Figs. 4, 4*a*).

This plant grows on the upper sandy beach especially near human habitations.

It is a prostrate rosette type with small, rounded leaves.

Its leaf structure is that of a typical succulent. The *upper epidermal cells* are large, thin-walled, of angular shape and uncutinized. Below this lies one or two layers of thin-walled *water storage cells*. The *chlorenchyma* tissue is compact and palisade-like, grouped around the veins in characteristic fashion. The *veins* are very abundant, small and free of stereome elements. They are surrounded by a *parenchyma sheath* free of chloroplastids but packed with starch

grains. Below the chlorenchyma more *water storage tissue* is found extending to the *lower epidermis* which is also uncutinized. The *stomates* are found on both the upper (99 per square millimeter) and the lower (83 per square millimeter) surfaces. They are level with the epidermal cells except on the upper surface where they are very slightly sunken. Subsidiary cells, which are much smaller than the adjoining epidermal cells accompany the stomates.

Sesuvium portulacastrum (Plate II., Figs. 5, 5*a*).

This pantropic strand plant is widely distributed throughout the Philippines along sandy beaches, forming solid patches in the fine sand of the upper and the middle beach. It is usually associated with *Canavalia, Vigna,* or with some of the beach grasses. Its large oblanceolate succulent leaves are often very thick and are composed chiefly of large water storage cells.

The *upper* and *lower epidermal cells* are uncutinized, and are comparatively thin-walled (3.5 microns to 5.4 microns). The *palisade* tissue is found just within the upper and lower epidermal layers, in layers of two to three cells thick. The rest of the leaf is made up of large *water storage cells* with very small fibrovascular bundles, free of stereome cells, scattered irregularly through the water tissue. An occasional crystal is found in the water cells. The *stomates* are found on both the upper (60 per square millimeter) and the lower (35 per square millimeter) surfaces. They are large, level with the epidermis, and are characterized by small cutinized outer beaks.

Cassytha filiformis (Plate III., Figs. 6, 6*a*, 6*b*).

This interesting parasitic member of the *Lauraceae* resembles the coarser species of *Cuscuta* of the Temperate Zone. The genus is Australian, but this species is pantropic in its distribution. It is locally abundant throughout the Islands on sandy seashores, or occasionally extending inland. Growing on the middle and the upper sandy beach or along the base of the rocky headland, it forms tangled masses of yellowish or greenish stems growing over and parasitizing practically all weeds, grasses, shrubs, and trees with which it comes in contact. When growing on the exposed middle beach, where it

often fastens itself on *Wedelia*, it is yellowish in color. When growing in shaded places it takes on a green color. The leaves are small and scale-like, protecting the bud. The photosynthetic function must therefore be carried on by the stem.

In cross-section the stem structure shows a single *epidermal layer* of heavily cutinized (6.3 microns), rectangular cells. The *cortex* is composed of one or two layers of rather small, rounded cells slightly thickened at their angles, which are free of chloroplastids, inward from which are several layers of *chlorophyll-bearing cells* elongated at right angles to the epidermis, appearing much like the palisade of a leaf. The small air spaces between the chlorophyll-bearing cells communicate with the larger air spaces below the stomates. *Mucilage cells* are scattered through the cortical tissue. There is no definite *endodermis*. Groups of very heavy-walled, small-lumened *cells* occur just outside the phloem. The *phloem* cells are thin-walled and small. The *protophloem* becomes crushed and disintegrated leaving a hollow space between the phloem and the thick-walled cells. An indefinite layer of *cambium* separates the phloem from the continuous ring of *xylem* made up of large pitted vessels and of smaller elements. The *protoxylem* is visible as small strands of tissue extending into the *pith* which is often rich in stored food.

The *stomates* are peculiar in that they are arranged in definite rows with their long axis at right angles to the long axis of the stem. They are accompanied by narrow subsidiary cells. One to several rows of cells separate adjacent rows of stomates. In cross-section the stomate is deeply sunken (25 microns). A heavy cuticular ridge forms an outer vestibule in the already narrow stomatal pore. The cavity of the guard cells are rather small and a partial inner vestibule is formed by cutinized ridges on the inner edges of the guard cells. The stomates number 81 per square millimeter of the surface of the stem.

Hernandia ovigera (Plate III., Figs. 7, 7*a*).

This large tree forms a part of the beach forest growing on the sand of the upper beach associated with *Terminalia catappa* and *Barringtonia asiatica*. Its hard round fruits incased in a bladdery envelope are characteristic objects in the beach drift.

The regular-sized *upper epidermal cells* are moderately cutinized (5 microns) with straight lateral walls. Two layers of compact palisade cells are characterized by the presence of very abundant, large *mucilage cells* of the same length as the palisade cells. The *sponge tissue* is very open with large air spaces, the lower layer being more compact and somewhat palisade-like. The *lower epidermal cells* are papillate and slightly cutinized (3.6 microns) with straight lateral walls. The stomates are sunken 12 microns below the level of the epidermal papillae. They are confined to the lower surface numbering 383 per square millimeter. Small subsidiary cells parallel the pore which is guarded by small cuticular ridges on the outer edge. The veins are numerous and free of *stereome* cells.

Prosopis vidaliana (Plate III., Figs. 8, 8*a*).

A shrub forming dense thickets along the seashore at Puerto Galera. It is found on the upper beach and forms a part of the shrubby growth, characteristic of the area. It usually occurs in pure stands and may have grasses, or *Sesuvium,* growing under it or nearby. Its small elliptical leaflets are smooth above and below.

Both the *upper* and the *lower epidermal layers* are slightly cutinized. Practically the entire mesophyll is made up of *palisade* cells. A few cells in the middle of the leaf are shaped like sponge cells but they do not form a complete layer and are chiefly noticeable near a vein or between two closely situated veins. The entire palisade is compact. The numerous *veins* are each surrounded by a sheath of colorless parenchyma. All but the smallest veins have some *stereome* tissue usually located below the *phloem.* Spool-shaped *stone cells* are found inward from the upper and the lower epidermal layers and lying parallel with the palisade. The *stomates* are found both on the upper (170 per square millimeter) and on the lower surface (108 per square millimeter). The stomates are slightly sunken (10 microns) in a cavity formed by the uparching subsidiary cells. The guard cells and the subsidiary cells are not cutinized, though the adjoining epidermal cells are. The lateral walls of the epidermal cells are straight.

Sophora tomentosa (Plate IV., Figs. 9, 9*a*, 9*b*, 9*c*).

This widely distributed leguminous shrub is typical of the upper part of the sandy beach associated with *Scaevola, Tournefortia, Wedelia,* and others.

Its leaflets are covered with silvery *hairs* all pointing the same way. These hairs are single-celled, thick-walled, and are seated on two basal cells somewhat sunken in the upper or the lower epidermis. These hairs are most abundant on the lower surface (33 per square millimeter) but are also found on the upper surface (20 per square millimeter). The regularly shaped cells of the *upper epidermis* are heavily cutinized with straight lateral walls. The mesophyll consists of three layers of *palisade* cells, the upper layer being compact, the lower two layers being somewhat open. An open *sponge tissue* follows, while a distinct *palisade* layer occurs just inside the lower epidermis. The *lower epidermal cells* are papillate with dome-shaped projections of cutin and are heavily cutinized throughout. The *stomates* are deeply sunken (28 microns) and are further protected by the over arching dome-shaped cutinized projections of the surrounding epidermal cells. There are 102 stomates per square millimeter on the lower surface and none on the upper. The *water storage cells* are found in groups situated inward from the upper and lower epidermal layers opposite the veins and usually connecting with them. The *veins* which contain a limited amount of *stereome* tissue are surrounded by cells containing simple *crystals*.

In certain older thicker leaves examined the palisade was much thicker, the water storage tissue more abundant and reaching to the veins, while the lower epidermal cells were much more papillate in structure and the stomates more deeply sunken.

Xylocarpus moluccensis (Plate IV., Figs. 10, 10*a*).

This small tree is found scattered along the upper beach, or at the base of rocky headlands, growing in the sand or among the rocks, with its roots frequently being reached by the tides. In the Philippines it is distributed from Central Luzon to the Sulu Archipelago, and its general distribution is from India to Madagascar, throughout Malaya to Polynesia. Merrill gives its habitat as "along open beaches, not in the mangrove."

Its leathery leaves show a number of xerophytic structures. A small-celled heavily cutinized (5.5 microns) *upper epidermis* is underlaid with a large-celled thick-walled *hypodermal layer*. A single layer of large thin-walled *water storage cells* is found below the hypodermis. The mesophyll of the leaf consists of two layers of *palisade cells* and of a *sponge tissue* the upper part of which is quite compact while the lower part is loose. The *lower epidermis* is also heavily cutinized. The lateral walls of both upper and lower epidermal cells are straight and thick. The very small *stomates* are level with the epidermis and are confined to the lower surface where they number 200 per square millimeter. They do not have subsidiary cells. The veins are infrequent and all but the smallest are accompanied by *stereome* cells.

Euphorbia atoto (Plate IV., Figs. 11, 11*a*).

This spurge is a common inhabitant of the sandy beach. The widely spaced plants, growing about one foot high are not confined to any particular part of the beach. It is found growing with *Sesuvium, Spinifex, Ipomoea,* and *Canavalia.* It is widely distributed in the Philippines, and is a characteristic beach plant of the Indo-Malayan region. Its small oblong leaves are greenish-white in color due to a waxy bloom.

The *upper epidermis,* free of hairs, is made up of smaller, less heavily cutinized (3.5 microns) cells than the lower epidermis (4 microns). The *palisade* and compact *sponge tissue* are clustered around the small veins which are free of *stereome* cells. A circle of *chlorophyll free cells* surrounds each vein. These cells have large nuclei and are abundantly supplied with starch. Two or three layers of *water storage cells* are located just above the lower epidermis. This accounts for the peculiar distribution of the *stomates* on the upper surface of the leaf (225 per square millimeter) as compared to the lower surface (45 per square millimeter). The stomates are slightly (12 microns) sunken below the general level of the epidermis. Anywhere throughout the mesophyll of the leaf *latex vessels* may be found.

Glochidion littorale (Plate IV., Figs. 12, 12*a*).

This plant forms thickets on the sandy beach or more usually along the shelving banks of tidal streams which are flooded at high tide.

Its leaf structure exhibits modifications which tend to conserve the moisture supply of the plant. The *upper epidermis* is composed of small cells, usually one layer, moderately cutinized (4 microns thick) with straight, thick, lateral walls and prominent nuclei. Below this is a *hypodermal layer* of larger cells, with much thicker straight lateral walls. The *palisade* is compact and is usually composed of one layer of long narrow cells. The *sponge* makes up over half of the mesophyll of the leaf. Its upper layers are open but its lower layers, the lowermost of which is palisade-like, are very compact. *Rosette crystals* are found in the sponge cells.

The *veins* are few and small, and are accompanied by a few *stereome* cells. The *lower epidermis* is composed of small papillate cells with the top of the papillae heavily (6 microns thick) cutinized. The lateral walls are thick and straight. The *stomates* are confined to the lower surface, they number 185 per square millimeter, and the narrow pores are paralleled by small subsidiary cells. They are deeply sunken (30 microns) below the papillate epidermal cells. Neither the small guard cells nor the subsidiary cells are cutinized while the outer wall of the epidermal cell is heavily cutinized and the lateral and the inner walls are of cellulose impregnated with cutin as is shown by their staining reaction.

Thespesia populnea (Plate IV., Figs. 13, 13*a*, 13*b*).

This small tree is characteristic of the upper beach and of the forests and thickets which occur on the sandy beach.

Its firm leaves are entirely free of hairs. The *upper epidermal cells* are regular in size and the outer walls are moderately thick (3.8 microns) but heavily cutinized (2 microns). A single very compact layer of *palisade* occupies the upper part of the mesophyll below which is a much looser layer of palisade. The *sponge tissue* is fairly open with very irregularly-shaped cells the lowest layer of which is palisade-like. Large groups of *slime cells* occur sparingly in the sponge. Strands of *water storage tissue* extend from upper to lower

epidermis at the veins and surrounding them. Most of these water storage cells contain rosette *crystals*. The *veins* are numerous and small, only the larger having a few cells of *stereome* tissue. The *lower epidermis* is cutinized and is interrupted by the very slightly sunken stomates. The *stomates* are confined to the lower surface where they number 188 per square millimeter. Scattered on the lower surface are small multicellular *glands* sunken in depressions in the epidermis.

Heritiera littoralis (Plate IV., Figs. 14, 14*a*, 14*b*; Plate V., Fig. 14*c*).

This large tree, with its entire, leathery leaves, forms a very characteristic part of the vegetation at the back of the mangrove swamp or along the sandy, or rocky, beach where its roots are often bathed by sea water. It is distributed throughout the Philippines.

In cross-section the leaf has a most striking appearance. The *upper epidermis* is composed of small cells, with thick, straight lateral walls. They are moderately (3.5 microns) cutinized. Below this is an *hypodermal tissue* from one to three cells in thickness, the cells of which are thick-walled and larger than those of the epidermis. Occasionally cells of the hypodermis, just below the epidermis, may be enlarged and contain *crystals*. At the veins the *hypodermis* is wider than usual. The *palisade* tissue is one cell layer in thickness and of a compact nature. Over half of the leaf is composed of a very loose *sponge tissue* which forms an excellent system of collecting cells, one funnel-shaped cell often being attached to several palisade cells and it in turn being connected to other cells below, the whole forming a very open tissue. These cells have large nuclei and large chloroplastids. The lowest layer of sponge is somewhat more compact than the other layers and a layer of cells along the veins is also compact. The *veins* are frequent and are placed at regular intervals. Opposite each vein is a narrow band of *thick-walled cells* extending up to the hypodermis and if the vein is large, extending also to the lower epidermis. All of the veins with their abundant *stereome* tissue are very conspicuous, dividing the mesophyll of the leaf into very definite areas, the whole giving the cross-section of the leaf a strikingly characteristic appearance. The *lower epidermis* is small-celled, the cells being moderately cutinized. The *stomates* are confined to the lower

surface and are very numerous, numbering 448 per square millimeter. They are small and are raised 12 microns above the general level of the epidermis. They open close under the overlapping peltate *hairs* which form a complete cover over the under side of the leaf. These hairs are many-celled and are attached at their center by a many-celled stalk. They overlap in various ways, some being entirely below the others, some entirely above, and others partly below and partly above. A very few of these hairs may be found on the upper surface.

Calophyllum inophyllum (Plate IV., Figs. 15, 15*a*).

A large tree found on the upper beach, forming a part of the beach forest and of the narrow fringe of trees characteristic of the upper part of the sandy beach. It is widely distributed throughout the Philippines and is a characteristic strand tree of the Indo-Malayan region. Its elliptical leaves are shiny and of a leathery texture.

The cells of both the *upper* and the *lower epidermis* have very wavy lateral walls and some of the cells are divided by from one to three cross walls. These wavy lateral walls cause the irregular size and shape of the epidermal cells, as seen in the cross-section of the leaf. Both the upper and lower epidermal cells are heavily cutinized (7.2 and 6.0 microns). Two and sometimes three layers of *palisade* cells of a compact nature underlie the epidermis while the lower part of the leaf is made up of a very loose *sponge tissue* the lower layer of which is palisade-like. This tree often extends branches out over the water in which case the leaves receive considerable additional light reflected from below. There are no *stomates* on the upper surface and they number 156 per square millimeter on the lower surface. The stomates are large, level with the epidermis, and have characteristic large subsidiary cells paralleling the stomatal pore. The guard cells have very prominent cuticular ridges on the outer edge while the lumen of the guard cell itself is very small. The subsidiary cells extend below the guard cells and below the epidermal cells. They appear to be filled with a brown substance of a homogeneous nature. The *veins* are few in number and most of them are large. The smaller ones are free of *stereome cells* but the larger ones are accompanied by heavy walled cells extending in a band three to four

cells wide from the upper to the lower epidermis. The margins of the leaf are heavily reinforced with stereome tissue.

Pemphis acidula (Plate V., Figs. 16, 16*a*, 16*b*).

This gray-leaved shrub is found both on rocky cliffs fronting the sea, and more frequently on the sandy beach, associated with *Scaevola, Sophora, Tournefortia* and *Wedelia*. It is occasionally found on low cliffs and rocky beaches close to the water's edge, clinging to the rocky substratum and yet apparently able to thrive. Its small elliptical leaves are gray from a hairy covering.

In cross-section both the *upper* and the *lower epidermal layers* show some cells which have divided into two or even three cells by horizontal walls. Usually in such cases the inner cell contains *mucilage*. These inner cells often protrude into the palisade. The outer walls of the epidermal cells are only slightly cutinized (3.7 microns) while the lateral and the inner walls are straight, thin, and of cellulose. Below the upper epidermis is a layer of compact *palisade* tissue from one to three cells thick. A similar but somewhat narrower layer of palisade occurs just above the lower epidermis. These palisade cells stain very deeply while in unstained paraffin sections they are brown, due, according to Areshcoug (1), to the brown liquid contents. The middle of the leaf is taken up chiefly with large thin-walled *water storage cells,* the upper and lower layers of which are palisade-like, the middle layers sponge-like in shape, though much larger in size. I have examined young leaves and found these water storage cells to contain a limited number of small chloroplastids which disappear as the leaf becomes older and acts more and more as a water storage leaf. This agrees with the findings of Areschoug. Scattered through this water storage tissue are groups of cells which stain deeply and are probably *mucilage- or tannin-containing cells.* Other groups of very small cells contain rosette *crystals* of calcium oxalate. Scattered over the upper (30 per square millimeter) and lower (22 per square millimeter) surface are straight thick-walled one-celled *hairs* sunken in the epidermis and extending almost parallel with it. They all point in the same direction, giving the leaf a silky appearance. The *stomates* are scattered in about equal numbers on the upper (48 per square millimeter) and the lower (46 per square

millimeter) surfaces. They are equally sunken (18 microns) below the epidermis on both surfaces. In cross-section the thick-walled guard cells show prominent cuticular ridges on their outer edges and a very slight ridge on the inner edge. The *veins* are few and small, located in the middle of the water tissue and are free of *stereome cells.*

Sideroxylon ferrugineum (Plate V., Figs. 17, 17*a*, 17*b*).

This large tree is commonly found scattered on the upper sandy beach or as a part of the beach forest. It is distributed throughout the Philippines and its leathery, shiny, elliptical leaves, and evil-smelling flower make it easy of identification.

In cross-section its leaves are characterized by a very thick *cuticle* (7.5 microns) overlying the rectangular *epidermal cells.* A compact *palisade tissue* composed of three layers of cells makes up half the thickness of the mesophyll. The lower layers of the palisade are shorter and somewhat less compact than the upper layer. The rest of the mesophyll is made up of an open *sponge tissue,* the lowest layer of which is palisade-like. The *lower epidermal cells* are very irregular in size, those next to the stomates being small. The lower epidermis is also very heavily cutinized though not quite as heavily as the upper. The *stomates,* which are located only on the lower surface, are small, are sunken 18 microns below the general level of the epidermis and number 225 per square millimeter. Several subsidiary cells accompany each stomate. The lower surface is protected by a covering of single-celled *hairs* which are all oriented the same way, are at different levels and overlap to some extent, thus forming a fairly complete cover. These hairs are flat and scale-like, fastened at their center to a short stalk which is deeply seated in the epidermal layer. Viewed from above these hairs are elliptical, pointed at both ends and show clearly their point of attachment. A few hairs are found on the upper surface also. The *veins* vary widely in size, are fairly abundant and are very conspicuous because of the abundance of *stereome tissue* which accompanies even the smallest veins.

Ipomoea pes-caprae (Plate V., Figs. 18, 18*a*–18*h*).

This herbaceous creeper is a very widely distributed inhabitant of the upper and middle beaches, sometimes sending its runners for many feet over the sand until its tip reaches the salt water and is killed back. It forms dense mats of vegetation and is associated with *Spinifex, Euphorbia, Canavalia, Vigna, Wedelia* and *Scaevola* as a typical pantropic strand plant. Its round leaves, notched at the tip, vary in size and thickness with age and habitat. They fold together along the midrib with their upper faces inward when heat and light are intense at midday.

Sun Form.—The old leaves, especially those growing in the sun, are very thick and fleshy, being often more than 800 microns in thickness. The *upper epidermis* is composed of regular-shaped cells with straight lateral walls and with *cuticle* which is slightly ridged, forming fine lines on surface view. The *veins* are few in number and scattered irregularly through the mesophyll. They are free of *stereome* cells. The *upper palisade* is composed of from two to three compact layers of cells. The central part of the leaf is made up of an extensive area of large-celled *water storage tissue* which may show the remains of chloroplastids, depending on the age of the leaf and the habitat in which it lived. The *lower palisade* is made up of from two to three compact layers of cells. The lower epidermis is similar to the upper.

Shade Form.—The leaves growing in the shade, are much larger and thinner, often only ⅓ the thickness of the sun form. The *epidermal cells* are quite large with straight lateral walls about the same thickness as in the sun form but less heavily cutinized. The *palisade* is formed of from two to three layers of small cells below which is a *region of more rounded cells* with very sparse, small chloroplastids. This region probably acts as a *water storage layer* and will lose its chloroplastids as the leaf becomes older. Around the larger veins these cells are entirely free of chloroplastids. The lower part of the leaf is composed of a loose sponge-like tissue but with most of the cells elongated at right angles to the leaf surface hence in reality a *palisade layer*. The *veins* are similar to the sun form.

The *stomates* are scattered about equally on both surfaces of the leaf and are accompanied by two rather large subsidiary cells arranged parallel to the pore. The sun leaves have a greater number of stomates per square millimeter than do the shade leaves, probably because the size of the leaf is smaller in the sun leaves than in the shade leaves.

	Upper	Lower	Upper	Lower
Sun	138	124	119	122
Shade	103	104	92	92

The sun leaves were obtained on the sandy beach open to direct heat and sunlight and were comparatively small and leathery. The shade leaves were growing in the shade of trees in a mixture of sand and black loam and the leaves were large and thin. The stomates are level with the epidermis on both surfaces of the sun and shade forms. They have rather prominent outer cuticular ridges.

Stomatal Closure.—A very interesting structure is noticeable in connection with the *stomates* of the sun leaf, particularly those on the upper surface. One of the subsidiary cells begins to enlarge until a vescicular swelling results, which bulges into the air chamber below the stomate and finally becomes cut off from the parent cell by a cross wall. This cell continues to proliferate until a number of cells are formed often completely filling the air chamber and crowding against the palisade cells. The central and largest of these cells has its outer wall closely pressed against the under side of the guard cells completely occluding the stomatal pore. This wall finally becomes heavily lignified even forming a slight papilla which forces its way up into the stomatal pore, effectively closing it. The rest of the cell walls remain unaltered. Haberlandt (14) reports a species of *Tradescantia* occluding its stomates by this peculiar method when grown in a drier atmosphere than usual. No occlusion of the stomates was noted in the shade form.

Sunken in depressions in the epidermis are many-celled thin-walled structures rich in protoplasm with prominent nuclei which are undoubtedly *hydathodes*. The lowest stalk cell penetrated into the palisade somewhat while the upper part is made up of many cells arranged in a rosette. These hydathodes are found in the sun form

on both the lower (11 per square millimeter) and the upper (8 per square millimeter) surfaces and are more abundant in the shade form than in the sun form.

Tournefortia argentea (Plate VI., Figs. 19, 19*a*).

A small gnarled tree with gray hairy leaves bunched at the ends of the thick twigs. It is characteristic of the upper sandy beach, being found on the outer edge of the so-called beach forest, or standing alone among the typical herbaceous beach plants such as *Ipomoea, Canavalia* and *Wedelia*. It is widely distributed throughout the Philippines and is a very characteristic strand plant of the Indo-Malayan region. The obovate leaves are supplied with *hair* on both surfaces, which gives them a grayish silky appearance. Although growing under severe conditions of exposure, the *upper* and *lower epidermal cells* are not heavily cutinized, probably because of the protection given the leaf by the unicellular unbranched hairs which arise as outgrowths of the epidermal cells.

A compact *palisade* of one or two layers lies below the upper epidermis. It is interrupted at intervals by strands of *water storage cells* which connect, chiefly opposite the veins, with the very extensive mass (5 cells thick) of large water storage cells which occupies the middle of the leaf. Below the water storage tissue are from two to three layers of loosely laid *palisade cells*. There is no sponge tissue. The *epidermal cells* are irregular in size. The *stomates* are found on both surfaces, there being 40 per square millimeter on the upper surface and 23 per square millimeter on the lower surface. They are level with the epidermis or even slightly raised. The *veins* are few in number and small, being entirely free of *stereome* cells.

Vitex trifolia (Plate VI., Figs. 20, 20*a*, 20*b*).

This shrub is found in thickets on the upper beach, chiefly in areas disturbed by man. It is widely distributed both in the Philippines and in the Indo-Malayan region. Its leaf structure, when growing in such regions, shows distinctly xerophytic structures. Its five to seven palmately compound leaflets are densely white-hairy on the under surface.

The *upper epidermal cells* are heavily cutinized (7.5 microns)

while the one or two *hypodermal layers* immediately below are also thick-walled. The mesophyll of the leaf is made up entirely of a very compact *palisade,* the deeper lying layers being somewhat less compact than the upper layers. The *water storage tissue* penetrates through the leaf at and around the veins and divides the mesophyll of the leaf into areas. The abundant but small veins have a very few *stereome* cells. The *lower epidermal cells* are uncutinized, practically all of them opposite the veins giving rise to characteristic two-celled *hairs.* The *lower epidermis* is somewhat wavy, the depressed areas between the veins being abundantly supplied with *stomates,* which are effectively protected by the overarching hairs. The stomates on the lower surface of the leaf are slightly raised (6 microns) above the level of the surrounding epidermal cells. They are confined to the lower surface where they number 260 per square millimeter.

Scaevola frutescens (Plate VI., Figs. 21, 21*a*).

This shrub with large delicate-appearing shiny leaves is widely distributed throughout the Indo-Malayan region as well as in the Philippines. It is characteristic of the upper beach, forming thickets together with *Wedelia, Pandanus, Tournefortia,* and *Quisqualis.*

The leaves are sessile, obovate, having a varnished appearance though their *cuticle* is not especially thick (1.5 microns). The prominent *upper epidermal cells* are only moderately cutinized, their outer wall being 4.5 microns thick. The *palisade* of three or four layers makes up about one-half of the mesophyll and merges gradually into the fairly compact sponge. The palisade cells are compactly arranged with only small air spaces between, but they are large, thin-walled and sparingly provided with chloroplastids. Very probably this tissue, as well as the sponge and the cells around the veins, acts in part as a *water storage tissue.* The *stomates* are small, level with the epidermis, and are confined to the lower epidermis, numbering 324 per square millimeter. The *veins* are small and infrequent, with almost no *stereome tissue* and are surrounded by a layer of parenchyma cells free of chloroplastids or containing them only on their outer sides. Large, slightly branched, irregular *stone cells* are found abundantly in the palisade and in the sponge tissue.

Wedelia biflora (Plate VI., Figs. 22, 22*a*).

Growing on the upper beach in bushy thickets or sprawling over shrubs is this widely distributed *Composite*. Occasionally it trails over the sands of the middle beach, its heart-shaped leaves when growing in such a habitat being small, thick, and rough to the touch. It is frequently found associated with *Prosopis, Scaevola* as well as with the smaller, lower growing grasses and herbs of the sandy beach.

The *upper epidermis* is made up of small cells, slightly cutinized (2.3 microns) with straight, thin lateral walls. Immediately below is a single layer of large thin-walled *water storage cells*. This water storage tissue penetrates the leaf from upper surface to lower surface at each of the numerous small *veins*. The rather open *palisade tissue* is made up of three cell layers, below which is an open *sponge tissue*, the lowest cell layer of which is somewhat palisade-like. The *lower epidermis* is thin, very lightly cutinized, with thin, wavy lateral walls. The *stomates* are small, with a narrow pore, and without subsidiary cells. They are level with the epidermis and are much more numerous (330 per square millimeter) on the lower surface than they are on the upper surface (10 per square millimeter). There is no *stereome tissue* at the veins.

Scattered on the upper surface, chiefly opposite the veins and to a lesser degree on the lower surface of the leaf, are *hairs* made up of three cells. The bulbous basal cell is imbedded in the epidermis and is thin-walled while the two terminal cells forming the hair are very thick-walled. The basal cell as well as the surrounding cells of the epidermis, which are radiately arranged around the base of the hair, are full of laminated protoplasmic contents. These surrounding epidermal cells have their outer walls heavily cutinized. It would appear from the structure and the location of these hairs that they are water absorbing hairs.

SUMMARY.

1. An intensive study was made of a beach area at Puerto Galera, Mindoro, Philippine Islands. The vegetation and the environmental factors of this area are in general similar to those of beach areas throughout the Islands.

2. The beach may be divided into several areas based on physio-

graphic features; each area having its characteristic flora. These areas are: (1) sandy beach, (2) rocky headland, and (3) muddy flats. The first two are considered here.

3. The sandy beach is characterized by creeping herbaceous forms, such as *Spinifex littoreus* and *Ipomoea pes-caprae,* with a shrub-tree zone on the upper beach composed chiefly of *Scaevola frutescens, Tournefortia argentea, Pandanus spp.* and various trees.

4. The rocky headland flora is derived in part from the sandy beach and in part from the interior forests. There are few species particularly distinctive of the rocky headland.

5. Measurements taken show a temperature on the beach which is fairly low and uniform, when compared with similar situations in the interior of the Islands, but very high when compared with that of Temperate Zone beaches.

6. Evaporation is high and occurs on the rocky headland, the sandy beach and under the mangrove trees in the ratio of 100; 58; 33.

7. Wind movement is strong and steady, particularly on the rocky headland and increases the evaporation greatly.

8. Intense sunlight, salt spray and rapid drying out of the sand together with the above mentioned factors produce a severe environment, particularly with regard to loss of water from the plant.

9. These severe environmental conditions have affected the habit, and particularly the leaf structure, of those plants typical of the beach.

10. The leaves of the twenty two beach plants examined exhibit many xerophytic structures, the most outstanding of which are: thick leaves (45 per cent are over 350 microns thick), water storage tissue (80 per cent), sunken stomates (45 per cent) and thick cuticle.

11. These features are fully described, summarized and illustrated.

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EXPLANATION OF THE PLATES.

PLATE I.

FIG. 1. *Spinifex littoreus* on sandy beach near Puerto Galera, Mindoro, Philippine Islands.

FIG. 2. *Ipomoea pes-caprae* on shelving bank on upper sandy beach, Manila Bay, Philippine Islands.

PLATE II.

FIG. 1–1*b*. *Spinifex littoreus.*
FIG. 1. Cross-section of leaf. × 110.
FIG. 1*a*. Diagrammatic cross-section of the entire leaf. × 27.
FIG. 1*b*. Stomate. × 335.
FIG. 2–2*a*. *Crinum asiaticum.*
FIG. 2. Cross-section of leaf. × 110.
FIG. 2*a*. Stomate. × 335.
FIG. 3–3*a*. *Allmania albida.*
FIG. 3. Cross-section of leaf. × 110.
FIG. 3*a*. Stomate. × 335.
FIG. 4–4*a*. *Trianthema portulacastrum.*
FIG. 4. Cross-section of leaf. × 110.
FIG. 4*a*. Stomate. × 335.

PLATE III.

FIG. 5–5*a*. *Sesuvium portulacastrum.*
FIG. 5. Cross-section of leaf. × 47.
FIG. 5*a*. Stomate. × 335.
FIG. 6–6*b*. *Cassytha filiformis.*
FIG. 6. Surface view of epidermal cells and stomates of stem. × 110.
FIG. 6*a*. Cross-section of stem from epidermis to within the wood cylinder. × 66.
FIG. 6*b*. Stomate. × 335.
FIG. 7–7*a*. *Hernandia ovigera.*
FIG. 7. Cross-section of leaf. × 110.

FIG. 7*a*. Stomate. × 335.
FIG. 8–8*a*. *Prosopis vidaliana.*
FIG. 8. Cross-section of leaf. × 110.
FIG. 8*a*. Stomata. × 335.

PLATE IV.

FIG. 9–9*c*. *Sophora tomentosa.*
FIG. 9. Cross-section of leaf. × 110.
FIG. 9*a*. Stomate. × 335.
FIG. 9*b*. Hair from upper surface. × 110.
FIG. 9*c*. Water storage cells opposite vein. × 110.
FIG. 10–10*a*. *Xylocarpus moluccensis.*
FIG. 10. Cross-section of leaf. × 110.
FIG. 10*a*. Stomate. × 335.
FIG. 11–11*a*. *Euphorbia atoto.*
FIG. 11. Cross-section of leaf. × 110.
FIG. 11*a*. Stomate from upper surface. × 335.
FIG. 12–12*a*. *Glochidion littorale.*
FIG. 12. Cross-section of leaf. × 110.
FIG. 12*a*. Stomate. × 335.
FIG. 13–13*b*. *Thespesia populnea.*
FIG. 13. Cross-section of leaf. × 110.
FIG. 13*a*. Stomate. × 335.
FIG. 13*b*. Gland from lower surface of leaf. × 110.
FIG. 14–14*b*. *Heritiera littoralis.*
FIG. 14. Cross-section of leaf. × 110.
FIG. 14*a*. Stomate showing relation to the hairy covering on the under side of the leaf. × 335.
FIG. 14*b*. Cross-section of hair from lower surface of leaf. × 110.
FIG. 15–15*a*. *Calophyllum inophyllum.*
FIG. 15. Cross-section of leaf. × 66.
FIG. 15*a*. Stomate. × 335.

PLATE V.

FIG. 14*c*. *Heritiera littoralis*—Peltate hairs from under side of leaf as seen in surface view. × 110.
FIG. 16–16*b*. *Pemphis acidula.*
FIG. 16. Cross-section of leaf. × 66.
FIG. 16*a*. Stomate. × 335.
FIG. 16*b*. Hair. × 110.
FIG. 17–17*b*. *Sideroxylon ferrugineum.*
FIG. 17. Cross-section of leaf. × 110.
FIG. 17*a*. Stomate. × 335.
FIG. 17*b*. Hair from under side of leaf in cross-section and in surface view. × 110.
FIG. 18–18*h*. *Ipomoea pes-caprae.*

FIG. 18. Cross-section of leaf (shade form). × 110.
FIG. 18*a*. Stomate. × 335.
FIG. 18*b*. Cross-section of leaf (sun form). × 110.
FIG. 18*c*. Hydathode. × 110.
FIG. 18*d*–18*h*. Stages in the occlusion of a stomate from the upper surface of leaf. × 110.

PLATE VI.

FIG. 19–19*a*. *Tournefortia argentea.*
FIG. 19. Cross-section of leaf. × 110.
FIG. 19*a*. Stomate. × 335.
FIG. 20–20*b*. *Vitex trifolia.*
FIG. 20. Cross-section of leaf. × 266.
FIG. 20*a*. Stomate. × 335.
FIG. 20*b*. Hair. × 335.
FIG. 21–21*a*. *Scaevola frutescens.*
FIG. 21. Cross-section of leaf. × 110.
FIG. 21*a*. Stomate. × 335.
FIG. 22–22*a*. *Wedelia biflora.*
FIG. 22. Cross-section of leaf. × 110.
FIG. 22*a*. Stomate. × 335.

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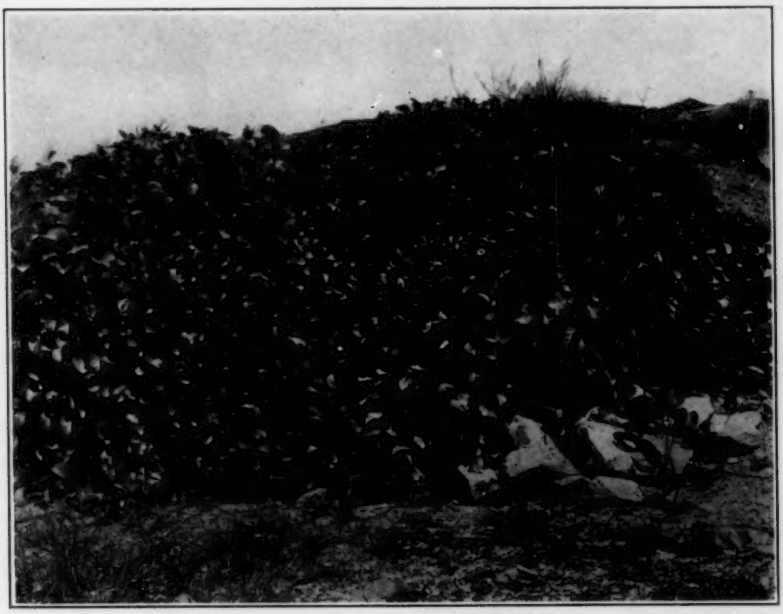

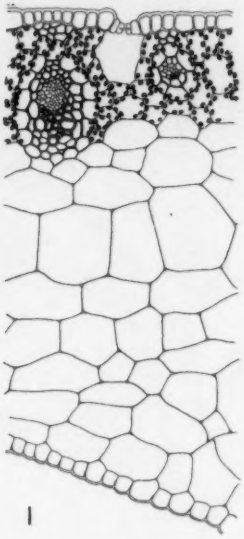

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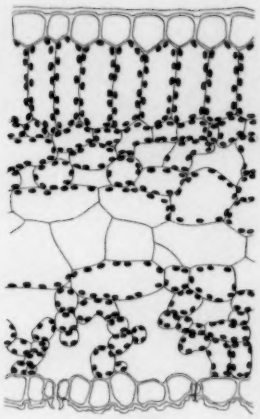

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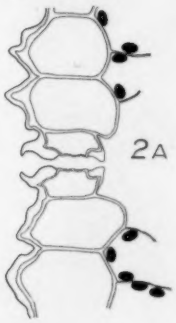

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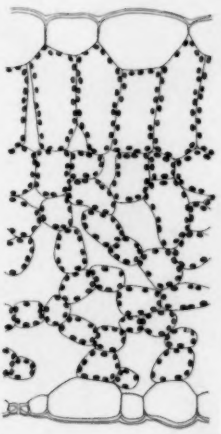

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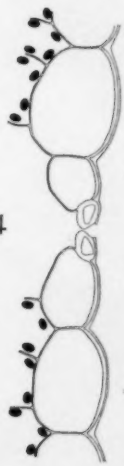

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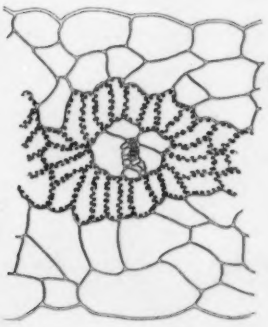

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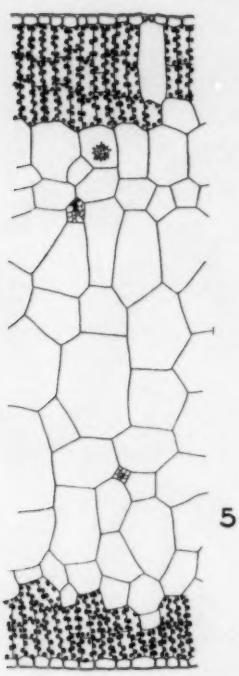

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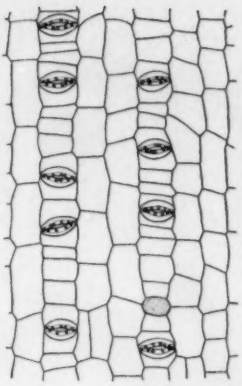

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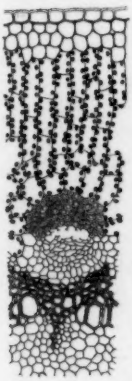

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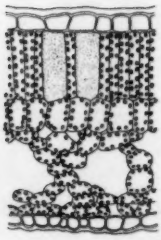

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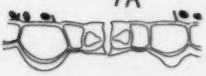

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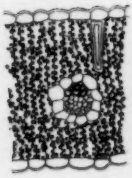

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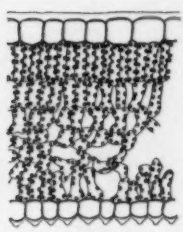

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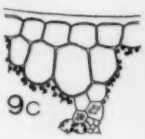

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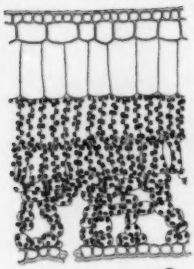

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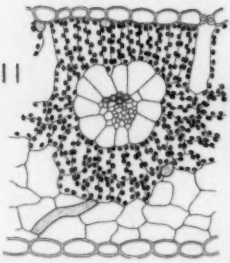

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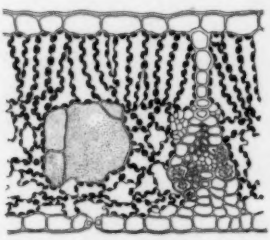

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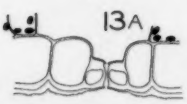

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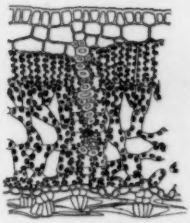

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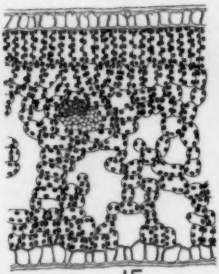

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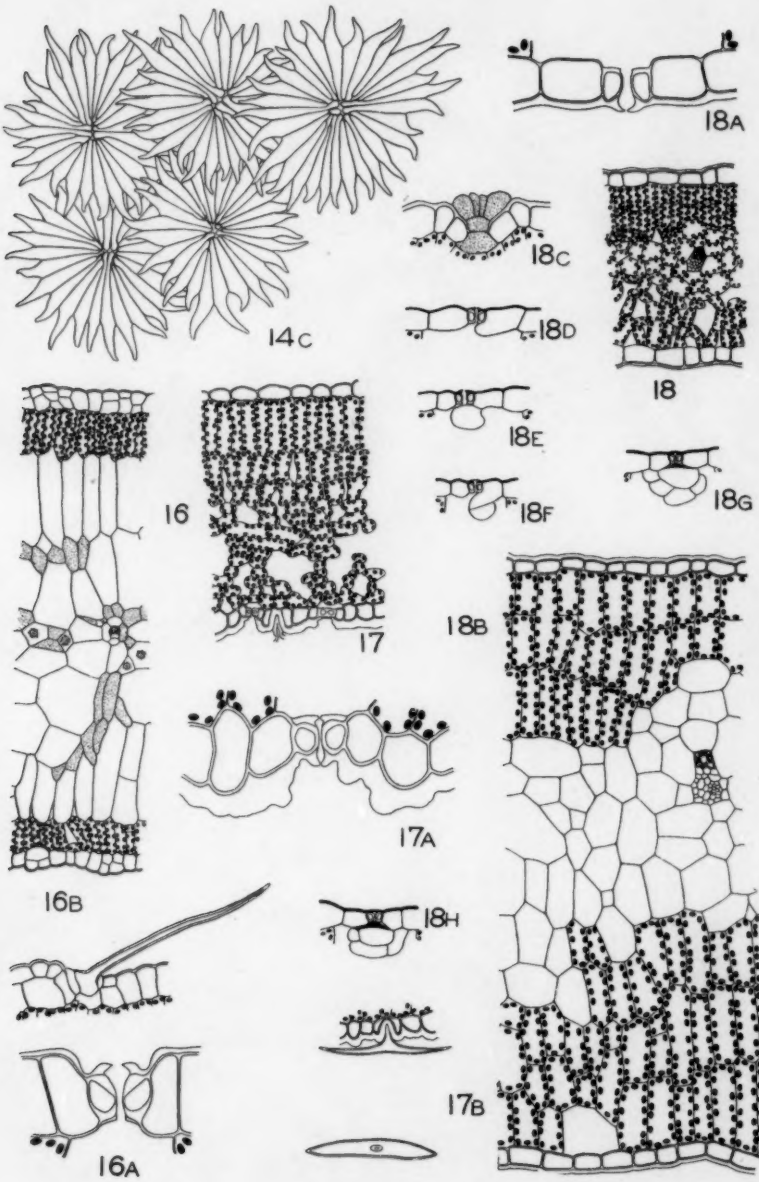
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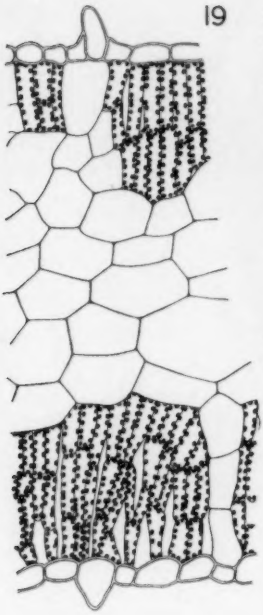

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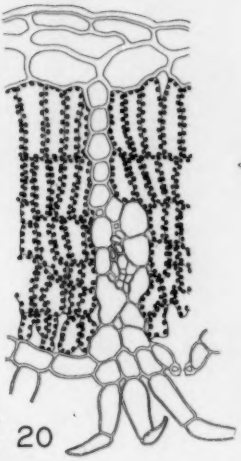

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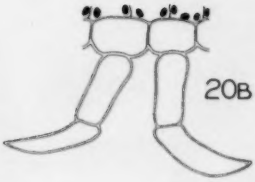

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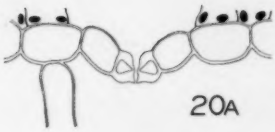

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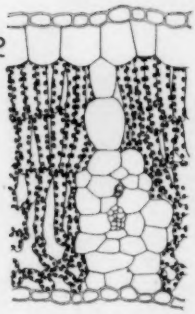

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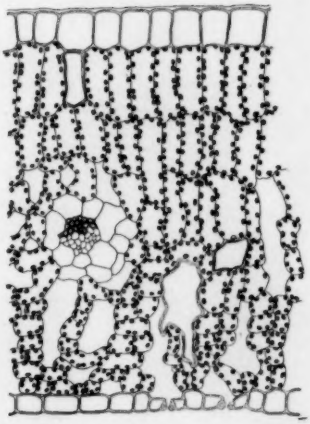

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